+ Stephen Roper. —

ROPER'S

QUESTIONS AND ANSWERS

FOR

STATIONARY AND MARINE ENGINEERS

AND

ELECTRICIANS

WITH A CHAPTER ON

WHAT TO DO IN CASE OF ACCIDENTS

Sixth Edition, Rewritten and Greatly Enlarged by

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PREFACE TO THE REVISED EDITION.

Like the early editions of the "Questions and Answers for Engineers," the present revision is intended for stationary engineers as well as those in the Mercantile Marine. At the time when this book was first written there were no published requirements for either of these two classes of service, and even at the present time it would be difficult to say just what should be the qualifications of stationary engineers. Some of the States have attempted to formulate the requirements, but there has been nothing evolved as yet which specifically states them. It would, in fact, be a difficult matter to comprise in one formula all branches of this service, but it is to be hoped that something in this direction will be accomplished in the near future by the co-operation of the various States and subsequent legislation.

For Marine Engineers the only requirements established by law are contained in the Regulations of the Steamboat Inspection Service of the Treasury Department. These, however, are stated in such a general way as to be of little service to an applicant in fitting himself for this service. As the requirements of the Mercantile Marine are very fully stated in the Frye Bill, introduced at Washington in January, 1892, the authors have deemed it advisable to make it a basis for the questions even though it did not become a law.

This bill is the result of certain recommendations from the U. S. delegates to the International Marine Conference and is based largely on the requirements in other countries. It contains not only rules governing the inspection of steamboats, but it states in a specific way just what shall be the qualifications of engineers. According to this bill, those in charge of the machinery on steamboats are divided into Chief Engineers and First, Second and Third Assistants. Such portions as have a direct bearing on the qualifications of these are here printed in full, but the subsequent questions and answers are confined to the first, second and third assistants' requirements. The authors have purposely omitted a detailed consideration of the requirements for chief engineer, not only because they are beyond the scope of Roper's series of books for practical engineers, but also because the chief engineer's qualifications are largely covered by the requirements of the assistants, excepting in so far as they relate to electrical matters.

A series of electrical questions and answers has been added for Dynamo Tenders and Wiremen. As the greater part of their work is confined to low pressure direct currents, it has been considered advisable to confine these questions to that class of work.

Of course, it would be impossible in a book of this kind to cover all of the questions that might confront an applicant on examination, and the authors have confined themselves to the more important subjects and selected such questions as in their judgment would on the one hand give a fair test of the knowledge of the applicant and, on the other, a well prepared engineer should be capable of answering.

The authors desire to express their obligations to the following gentlemen who have so kindly assisted them in the preparation of various parts of the book. To Mr. Samuel B. Locke, for practical questions for Firemen and Stationary Engineers; to Mr. W. H. Thorne, for questions for Marine Engineers; to Augustus Koenig, M. D., for the chapter on "What to do in Case of Accidents."

EDWIN R. KELLER.
CLAYTON W. PIKE.

PHILADELPHIA, August, 1900.

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QUESTIONS AND ANSWERS

FOR

STEAM ENGINEERS

AND

ELECTRICIANS.

QUESTIONS FOR FIREMEN.

Q. How would you classify steam boilers?

A. Into cylindrical, flue, fire tubular, and water tubular.

Q. What advantages does the plain cylinder boiler possess over other types?

A. It is simple, inexpensive, easy to clean and repair.

Q. Are plain cylinder boilers much used at the present time?

A. No; they have disappeared almost entirely, mainly on account of their inefficiency. They are found occasionally in localities where the cost of fuel is very low.

Q. Name the principal varieties of flue boilers and briefly describe their characteristics.

A. The Cornish, Lancashire, and Galloway boilers are the principal varieties of flue boilers. In the Cornish type an internal cylindrical flue extends the whole length of the boiler, and the furnace is usually contained in the flue. The Lancashire boiler has two internal flues with a furnace in each, the two flues uniting into one behind the bridge wall. The Galloway is similar to the Lancashire, but has a number of conical tubes, called Galloway tubes, inside and across the flues, through which the water circulates. The furnaces are either within the flues or external.

Q. What are the relative advantages and disadvantages of the above-named boilers?

A. The Cornish boiler has a greater heating surface than the plain cylindrical boiler, and it has the further advantage that that portion of the shell on which the scale is deposited is the coolest instead of the hottest point. It has the disadvantage that for the same water capacity it must have a greater diameter.

The Galloway boiler, being virtually a modified Lancashire boiler, possesses all of its advantages; and, additionally, on account of the conical tubes, which are placed transversely in the flues, it has a greater heating surface and better circulation. Furthermore, the flues are much less liable to collapse. All of this is accomplished by the Galloway tubes. Of the three boilers mentioned, the Galloway type is the safest and most economical in the use of fuel.

Q. What methods are employed to stiffen the flues of boilers and to provide for linear expansion and contraction?

A. This end was formerly accomplished by making the flues in short lengths and connecting them by U-shaped rings, riveted on each section of flue. The stiffening of the flue alone is also accomplished by placing U-shaped rings within the flues, at intervals, and by the use of Galloway tubes. This, however, does not take care of expansion and contraction. The best way of accomplishing both ends is by corrugating the flue, which has the further advantage of increasing the heating surface without taking up any more space in the boiler.

Q. What is meant by fire-tube or tubular boilers?

A. Fire-tube or tubular boilers are those in which the combustion gases pass, not only around the outside shell, but also through tubes which are surrounded by water.

Q. In what respect do they differ from flue boilers?

A. In no essential feature, except that instead of one flue of large diameter there are a number of small flues or tubes.

Q. What is the difference between internally and externally fired tubular boilers?

A. The internally fired type consists of an external cylindrical shell containing a furnace extending from the front of the boiler to a point about midway in the length of the boiler. From this point, and extending to the rear end of the boiler, there are a number of tubes which lead the gases of combustion to the back, whence they pass under the outside shell to the front and into the stack. In the externally fired type the tubes extend the whole length of the boiler, and the furnace is outside and under the front end of the boiler. The products of combustion pass along the bottom of the shell to the back of the boiler, and then return through the tubes to the front where they enter the stack connection. This latter type is frequently called the "Return Tubular."

Q. What advantages does a tubular boiler possess over the cylinder and flue boilers?

A. The tubular takes up less room, generates steam more rapidly, and requires less fuel; moreover, tubes are less dangerous than flues, on account of their small diameter and great strength.

Q. Why are tubular boilers more economical than plain cylinder and flue boilers?

A. Because their heating surface is much greater, and consequently the greater portion of the heat contained in the combustion gases is imparted to the water.

Q. What are their disadvantages as compared to the above-mentioned types? Are they important?

A. The disadvantages are that the first cost is greater, and that they are more difficult to clean and repair, because they are less accessible. These disadvantages are unimportant compared to the great gain in economy.

Q. What may be said about the tubular boiler in regard to safety?

A. The tubular boiler is just as safe as the cylindrical boiler, and more so than the flue boiler, because the parts subjected to internal pressure have the same strength, while those subjected to external pressure, being smaller in diameter, are much stronger.

Q. What is a water-tube boiler?

A. It is one in which the water circulates through a series of tubes, which are surrounded by the combustion gases.

Q. What is the position of the tubes in this class of boilers?

A. Different makers place the tubes in different positions. In the most common type, such as the

Babcock and Wilcox, Heine, Gill, and Root, the tubes are inclined; in others, such as the Cahall, they are vertical, and occasionally they may even be found curved spirally.

Q. What are the principal advantages of the water-tube boiler as compared with other types?

A. Its advantages are that it is safer, more economical, steams more rapidly, is easily repaired, more durable; its form may be adapted to almost any existing conditions, and it may be easily taken apart and transported. Its only disadvantages are that it is heavy and expensive.

Q. Why is it durable?

A. Because it is easily accessible, and because, as already stated, it adapts itself to the varying expansion and contraction without producing undue strains; further, the circulation is good, and consequently the temperature of the different parts is fairly uniform.

Q. To what class do locomotive and marine boilers belong?

A. They may be said to belong to the tubular type, but they have certain characteristics not found in the ordinary tubular boiler, which really place them in separate classes by themselves.

Q. Give a brief description of a modern marine boiler.

A. It usually consists of a short, circular shell of large diameter, with an internal corrugated furnace. At the back of the furnace is a chamber into which the gases pass from the furnace. This is called the back up-take. A similar chamber in the front, called the front up-take, connects with the stack. The tubes are placed above and around the furnace, and extend from the front to the back up-take.

Q. What, then, is the essential difference between a marine boiler and an internally fired tubular boiler?

A. The principal difference is that while in the ordinary internally fired tubular boiler the gases pass from the furnaces through tubes to the back and then along the outside to the front, in the marine boiler the gases do not pass around the outside at all, but go from the furnace directly into the back up-take, thence through the tubes to the front up-take and into the stack.

Q. What conditions have brought about this design of boiler for marine purposes?

A. For marine purposes a boiler must be short, as otherwise it could not be set and operated in the available space ; and it must be self-contained, because brick setting, on account of its great weight and the motion of the ship, would be out of the question. It must also make steam rapidly.

Q. Are marine-type boilers ever used for stationary purposes?

A. Yes; where the vibration is so great as to make it impossible to make use of a brick setting.

Q. Describe briefly a locomotive boiler.

A. A locomotive boiler consists of a long cylinder that contains a large number of tubes, at one end of which is the fire-box or furnace, frequently made of copper, in which the grate bars are contained. The shape of the fire-box and the end of the boiler shell which incloses it is rectangular.

Q. What is the path followed by the products of combustion?

A. They first strike a fire-brick arch, which deflects them into the tubes through which they pass into the funnel or smoke-stack placed at the front end.

Q. How is sufficient draft obtained?

A. In the case of the actual locomotive, by exhausting steam from the cylinders into the funnel. When this type of boiler is used for stationary work, a sufficiently high stack is employed to give the necessary draft.

Q. How are the flat surfaces of the fire-boxes made sufficiently strong in this type of boiler?

A. By short stay-bolts that are connected with the outside shell of the boiler.

Q. How is steam taken from locomotive boilers?

A. Usually from a steam dome that is placed on top of the boiler shell.

Q. Why is this steam dome used?

A. To make sure of obtaining dry steam.

Q. Is any other arrangement used?

A. Yes; dry pipes.

Q. What do you mean by a one horse-power boiler?

A. One which evaporates 30 pounds of water per hour from a temperature of 100° Fahr. to steam at a pressure of 70 pounds.

Q. What materials are used for boiler shells?

A. Wrought iron and steel, mostly the latter.

Q. Why is steel better?

A. Because it is lighter for the same strength, and therefore a thinner plate may be used which makes the heating surface more efficient.

Q. What is the difference between longitudinal and curvilinear rivets?

A. The longitudinal rivets are those that run lengthwise of the boiler, and the curvilinear are those that run around the circumference of the shell.

Q. What is the first duty of a fireman in taking charge of a boiler?

A. He should examine the water and see if it is at a proper level.

Q. At what level should the water stand in a gauge-glass?

A. It should be kept up to the second gauge while working, and at night should be raised to the third gauge.

Q. Why should the level of the water be raised at night?

A. To insure against the water becoming too low from leakage or evaporation.

Q. Suppose the water should become dangerously low, what should the fireman do?

A. He should at once draw the fire and allow the boiler to cool.

Q. Should he admit any cold water to the boiler?

A. On no account.

Q. Should he attempt to raise the safety valve in order to diminish the steam pressure?

A. Never; as this would be positively dangerous.

Q. Why is it dangerous to raise the safety valve?

A. Because this would suddenly lessen the pressure in a boiler, and the water would be permitted to rise and perhaps come in contact with the overheated iron, which might cause an explosion.

Q. Suppose the water supply should be cut off for a short time, how should the fireman proceed?

A. He should cover his fire with fresh coal, and shut off all steam engines or other steam-using devices.

Q. In getting up steam, how should the fireman proceed?

A. First, he should find out if the water is at a proper level, trying the gauge-cocks for this purpose, remove all ashes and cinders from the furnace, and then cover the grate with a thin layer of coal. He should then place wood and shavings on the coal, after which he can start the fire.

Q. Why is it advantageous to place a little covering of coal on the grate before putting on the wood and the shavings?

A. It protects the cold grate bars from the heat of the fire and it also saves fuel, since the heat that would be transmitted to the bars is absorbed by the coal.

Q. Is there any advantage in starting the fire gradually and slowly when commencing to get up steam from cold water?

A. Yes; it allows the parts of the boiler to expand equally, and therefore it throws less strain on these parts.

Q. How should a fireman regulate his fire?

A. He should keep the fire at a uniform thickness over all parts of the grate, not allowing any bare spots or any accumulations of ashes or dead coals at any part of the furnace; he should supply the coal in small quantities at frequent intervals; he should avoid excessive firing as much as possible, as it is always attended with more or less danger, since the intense heat repels the water from the surface of the iron and this causes the plates to burn.

Q. How thick should the fire be?

A. This depends upon the capacity of the boiler relative to the engine and upon the coal used. If anthracite coal be used, the thickness of about 3 inches is proper, and for soft coal about 5 inches. If the boiler is too small for the work, it will be necessary to keep the fire thin; if, however, the boiler is extra large, the thickness of the fire makes little difference.

Q. Suppose from any cause the fire becomes very low, what should the fireman do?

A. He should place shavings, sawdust, wood, or other very combustible substances on the bare spot with a thin covering of coal and then open the draft to its full extent. He should not poke or disturb the fire, as this is likely to put it out.

Q. Is the regulation of the draft of a furnace of much importance?

A. Yes; it is next in importance to the regulation of water, because by poor regulation of the draft enormous quantities of coal are wasted.

Q. How should the draft be regulated in order to obtain best results from the fuel?

A. There should be no more draft at any time than would produce sufficient combustion to keep the steam at the working pressure; any greater supply of air than this carries great quantities of heat into the chimney, which is lost.

Q. Can this principle of regulation be carried out always?

A. Not unless the furnace and the boilers are sufficiently large to do their work without forcing; if the boiler is too small, it is impossible to use the fuel economically.

Q. Why should the ashpit be kept clean?

A. Because if it is filled with ashes and cinders, the grate bars become overheated and may be either badly warped or melted.

Q. Is it objectionable to throw steam or water under the grate bars of boilers?

A. Yes; because water forms with the ashes a lye that corrodes the iron.

Q. What care should the fireman give to the safety valve?

A. He should keep it at all times in good working order and should try it at least once a day, preferably in the morning, so as to see that all the parts are in good working order before getting up steam.

Q. In filling boilers, why is a cock or valve in the steam room of the boiler often open?

A. In order to allow the air to escape so that it may not collect in the steam room, thus retarding the entrance of the water and preventing the regular expansion of the iron after the fire is started.

Q. Explain what you mean by the steam room of the boiler.

A. That portion of the boiler occupied by steam above the water.

Q. What do you mean by the fire line of the boiler?

A. The line above which the fire cannot rise because of the masonry which surrounds the boiler.

Q. How often should boiler flues and tubes be cleaned?

A. At least once a week.

Q. Should the outside shell of the boiler also be cleaned?

A. Yes.

Q. What is the advantage gained by cleaning the flues frequently and the removing of soot and ashes from the boiler shell and tubes?

A. It saves fuel; it also saves the burning of the tubes or plates.

Q. How often should the fireman clean his boilers?

A. This depends upon the kind of water used; but no matter how good the water, he should clean his boiler at least every three months.

Q. What is the duty of a fireman in regard to blowing out his boilers?

A. He should blow them out regularly and carefully; the condition of the feed water being what determines how often this should be done. In blowing them out the dampers should be closed and the fire drawn. Then as much time as possible should be allowed the boiler to cool off before opening the blow-off cock. An entire day is not too much to allow for cooling.

Q. Why is it bad practice to blow off a boiler while hot?

A. Because in cooling without any water unequal strains are liable to be produced, and also the scale and mud become hardened by the heat and stick to the boiler, thus defeating the object for which the boiler is blown off—namely, the removal of scale and mud.

Q. What else should be done at the time of cleaning the boilers?

A. The fireman should examine all the seams and stays and rivets, crown sheet, etc., and should also sound the shell of the boiler with a very light steel hammer, in order to determine the condition of the iron.

Q. How often should the steam gauge be tested?

A. At least once a year.

Q. Can the fireman usually test the steam gauge himself?

A. Not unless he has access to a test gauge, which is not often the case.

Q. How can the fireman clean his water-gauge glass inside?

A. Open the drip-cock and close the water valve which will allow the steam to rush down the glass and carry out any dirt that is in it. When the boiler is cool, the glass can also be swabbed out with a piece of cloth on a stick.

Q. Is it advisable to use a piece of wire or iron instead of a stick?

A. No; as it is likely to crack the glass.

Q. What can you say about the care of the gauge cocks?

A. They should be examined several times a day, to make sure that they are in good working order; they should be shut tight, and should be ground or repaired whenever necessary so as to make them tight.

Q. What would you do in cold weather if you thought that your pumps, boiler connections, or water pipes were liable to be frozen?

A. I would open all drip- or discharge-cocks and allow the water to run out of them when I stopped work at night. In the morning I would examine all the steam- and water-connections before starting the fires.

Q. What would you do in case it becomes necessary to stop the engine and steam should commence to blow off at the safety valve?

A. I would immediately start the pump or injector and cover the fire with fresh coal.

Q. Is it desirable to have the damper open at the same time as the fire door?

A. No; the door and damper should never be open at the same time, because the cold air would rush through the open door above the fire and strike on the tube and crown sheets, which would be liable to contract the seams and cause leakage.

Q. How would you proceed if you wished to examine the check valve while the steam is on the boiler?

A. I would first close the stop-cock between the check valve and boiler; then I would unscrew and remove the check.

Q. Describe how you would make a joint on the manhole or handhole of the boiler.

A. I would first remove all gum or other material from the seat flange where the joint is to be made, and would then put on the gasket and tighten the nut.

Q. How often should you consider that a good fireman should make a thorough examination of everything under his charge?

A. He should, at least once a day, make a thorough examination of all safety valves, pumps, injectors, steam- and water-connections, etc.

Q. What is scale in a boiler?

A. It is a deposit that forms on the inside of a boiler shell or tubes.

Q. From what does this deposit come?

A. From impurities in the feed water.

Q. What are the results of scale in boilers?

A. It increases the coal consumption and causes burning of the plates.

Q. Why does it increase the coal consumption?

A. Because the scale being a poor conductor of heat, the heat of the fire is not imparted to the water as completely as if the water was directly in contact with the plate.

Q. Why does the deposition of scale increase the tendency of the plates to burn?

A. The water, not being directly against the iron, does not protect it from crystallization or burning.

Q. How can the formation of scale be guarded against?

A. In two ways: *first*, by depositing the impurities in water in feed-water heaters of the open type before the water gets into the boiler; *second*, by the use of boiler compounds in the boiler.

Q. Is there any boiler compound that will be effective in all cases?

A. No; the composition of the compounds should be varied according to the nature of the impurities that are contained in the feed water.

Q. What is corrosion?

A. Corrosion is the wasting or pitting of iron in the boiler.

Q. To what is it generally due?

A. Corrosion on the outside of a boiler is generally due to the chemical action of sulphur or other impurities in the fuel or in the atmosphere. Corrosion on the interior of the boiler is caused by the chemical action of acid or mineral substances in the feed water.

Q. What remedies are employed to prevent corrosion?

A. The interior of the boiler is often painted with a thin coating of Portland cement; another method is to allow a thin layer of scale to form; still another method is to suspend metallic zinc in the water and steam spaces.

Q. What is foaming, and where would it be noticed?

A. Foaming is a violent movement of the water; it is noticed at the gauge glass by the rapid rise and fall of the water level.

Q. What causes foaming in boilers?

A. Foaming may be due to poor design of the boiler that has provided an insufficient amount of steam space. If the boiler is properly designed in this respect, foaming will be due to the foul condition of the boiler or to the presence of some soapy or greasy substance in the feed water.

Q. Is foaming a source of danger?

A. Yes; when a boiler foams badly the water is lifted from the fire surface of the boiler, which allows the iron to be burned.

Q. Is there any danger to the engine in case of foaming?

A. Yes; mud and water from the boiler are liable to be carried into the cylinder of the engine, and either scratch the cylinder surface or perhaps cause the breaking of the cylinder head.

Q. What steps should you take to prevent foaming?

A. I would check the boiler and endeavor to obtain pure feed water.

Q. What is priming?

A. Priming is the carrying over of water from the boiler to the engine in the form of spray.

Q. What causes priming?

A. Sometimes a lack of sufficient steam space in the boiler, but if properly designed in this respect it will be due to carrying the water at a too high level.

Q. For what is a safety valve used?

A. It is intended to protect the boiler from explosion by relieving the pressure of the boiler whenever it gets beyond a certain amount.

Q. What is the general principle on which a safety valve works?

A. The steam pressure in the boiler is balanced against the pressure of a spring or weight in such a manner that when the pressure in the boiler exceeds a safety limit it will overcome the action of the spring or weight and open the valve. This allows the escape of steam and thus diminishes the pressure.

Q. What is the effect of the continual action of the steam on the safety valve?

A. The valve becomes worn and leaky and must be occasionally ground on the seat.

Q. What material would you use for the grinding?

A. Powdered glass, grit from grindstones, or fine emery.

Q. How often would you test a safety valve, and when?

A. At least once a day—in the morning—so as to be sure that it is in good working order before starting the fire.

Q. What classes of safety valve are you familiar with?

A. Three classes: *first*, the dead-weight safety valve, in which the weight that balances the pressure of the steam is placed directly on the valve spindle; *second*, a spring safety valve, which is like the first except that the spring takes the place of the weight; *third*, the lever safety valve, in which the weight or spring, instead of being placed directly on the valve spindle, is attached to a lever.

Q. How are the adjustments made with a lever valve?

A. By altering the position of the weight or spring on the lever.

Q. How many safety valves should a boiler have?

A. At least two.

Q. What are the principal gauges used in connection with steam boilers?

A. The water gauge, pressure gauge, and vacuum gauge.

Q. When there is no steam on the boiler, where should the pointer of the pressure gauge stand?

A. At zero.

Q. Suppose that it does not stand at zero?

A. It should be adjusted by comparison with a standard gauge.

Q. What is a water gauge?

A. An apparatus for showing the level at which water stands in a boiler. It consists of the glass tube placed on the outside of the boiler, the top end being connected to the steam space and the bottom end to the water space.

Q. What is a safety water column?

A. A modification of the water gauge, consisting of floats so arranged that a signal is given whenever the water is too high or too low.

Q. Is it safe to depend upon the indications of the safety water column?

A. No; while they are useful as an additional safeguard in maintaining the proper level of the water, a fireman must on no account neglect to watch the level in the water gauge.

Q. What other device is used for finding out the water level?

A. Gauge cocks (usually three in number) placed at different levels.

Q. How often should these gauge cocks be tried, and why?

A. Several times a day, because the gauge-glass connections may become choked and cause the glass to give incorrect indications of the level of the water.

Q. What are pumps, and how are they usually operated?

A. Pumps are machines for lifting or transferring water or other liquids. They are operated either by belting, by steam, or by connection to an electric motor.

Q. Which of the above types is usually employed for boiler-feed pumps?

A. The steam pump.

Q. What different kinds of steam pumps are there?

A. Fly-wheel pumps, direct-acting pumps, and duplex pumps.

Q. Which of these pumps is most commonly used for a boiler-feed pump, and why?

A. The duplex pump, because it is the simplest.

Q. What is a duplex pump?

A. Duplex pumps consist of a combination of two steam pumps so coupled together that the steam valve of one is operated by the piston of the other.

Q. Explain the difference between a force pump and a suction pump.

A. A force pump is one that forces the water against some opposing pressure, such as the pressure in the boiler; and a suction pump is one that takes water from a level below that of the pump and raises it—as, for example, an ordinary well pump.

Q. Is there any limit to the height to which a suction pump will draw water?

A. Yes; it cannot lift water more than 33 feet vertically.

Q. Is there any limit to the height to which a pump will force water?

A. None, except the power of the pump.

Q. What is an injector?

A. An apparatus for forcing water against a pressure by the direct action of a jet of steam on the water.

Q. Injectors frequently fail to operate. What is the common cause of this failure?

A. The presence of air in the suction pipe.

Q. How would you avoid this?

A. I would make sure that the end of the suction pipe was entirely in the water, that the valve stem was properly packed, and that there was no sediment or dirt in the nozzle.

Q. If an injector was not getting water, where would you look for trouble?

A. I would first examine the water pipe, then see if the strainer was clogged; then, if the trouble were due to neither of these, it might be due to too hot water or too low a steam pressure.

Q. If after the injector has once started the jet of water breaks, where would you look for the difficulty?

A. It might be due to any of the above causes or to a loose disc in the supply pipe valve.

Q. What are the principal precautions to be used in setting up injectors?

A. All pipes must be at least as large as the holes in the corresponding branch of the injector, and must be as short and straight as possible. A strainer should be placed over the end of the water-supply pipe. The area of all holes in the strainer must be considerably greater than the area of the water-supply pipe, so as to compensate for the closing of some of them by deposits of sticks or other matter. Steam should be taken from the highest part of the boiler, so as to get it as dry as possible, as wet steam cuts the steam spindle and nozzle of the injector. It is not advisable to take steam from the engine supply pipe unless this pipe is very large, as the sudden variations in pressure may break the jet. After the injector is properly connected it should be thoroughly washed out by blowing steam through it, so as to take out all the red lead or any other solids that may be in the pipe.

Q. Should injectors be set high or low?

A. As low as possible, since their capacity diminishes and also their reliability as to the height of the lift is increased.

Q. What is an ejector?

A. An instrument similar to the injector, and designed only to lift water without forcing it against a pressure.

Q. What is an inspirator?

A. A double jet injector; one jet is used to lift the water, the other to force it into the boiler.

Q. Should a boiler plant have both a pump and an injector?

A. Yes; because either one may at some time refuse to operate.

Q. What is the object in heating feed water before it goes in the boiler?

A. There are several reasons for doing so: *first*, because if the water were fed into the boiler cold, it would produce strains in the boiler which would tend to shorten its life; *second*, because heating the feed water to a high temperature will cause a large proportion of the salts contained in the solution to separate out and to be deposited in the heater instead of producing scale in the boiler; *third*, if the heater is supplied with exhaust steam or with some other source of heat which would otherwise be wasted, there is a considerable saving of fuel.

Q. What is the difference between open and closed heaters?

A. In closed heaters the exhaust steam passes through a series of brass tubes and the feed water passes through a space around the tubes and into the boiler; or, the opposite arrangement may be used, the water passing through the tubes and the steam around the tubes. In open heaters the steam comes in actual contact with the water.

Q. What is an economizer?

A. An economizer is a device used for heating feed water which makes use of the products of composition passing from the boiler furnace into the stack.

Q. How are economizers generally made?

A. They are usually made of a series of iron or steel tubes connected at each end by headers like those used in water-tube boilers. The feed water circulates through the tubes and the products of composition pass around the tubes.

Q. What is a grate, and for what purpose is it used?

A. A grate consists usually of a series of cast-iron bars supported at either end and placed in the furnace chamber, its object being to support the fuel in such a manner as to allow the free passage of air through the fuel.

Q. What limits the length of the grate?

A. The distance to which the fireman can throw the coal, which is about 6 feet.

Q. What is the object in inclining the bars downward toward the bridge wall?

A. To make the distribution of fuel more easy.

Q. How much coal is generally consumed per square foot of grate surface?

A. This depends entirely upon the draft and the kind of coal.

Q. How much anthracite coal would you expect to be burned in a good stationary boiler?

A. About nine (9) pounds.

Q. Roughly, how much grate surface is allowed per horse-power?

A. In stationary boilers about $\frac{1}{3}$ of a square foot.

Q. What is a shaking grate?

A. It is a grate operated mechanically, which moves in such a way as to clean the fire, break up the clinkers, and remove them without opening the fire door.

Q. What is the advantage of a shaking grate?

A. It does away with the necessity of opening the fire doors frequently, and since the entrance of cold air in the fire door tends to create strains in the boiler the use of the shaking grate would increase the durability of the boiler. Also, it is impossible for a fireman to thoroughly stir up with the slicing bar every part of the grate; therefore, if the coal used had a tendency to form clinkers, the shaking grate would be an advantage, because all parts of the fire would be reached by its action.

Q. What do you mean by automatic stoking?

A. Feeding the coal and removing the ashes from the furnace automatically without opening the furnace doors.

Q. What advantages are claimed for mechanical stokers?

A. Saving of fuel, prevention of smoke, and less hand labor.

Q. Why should a mechanical stoker save fuel?

A. Because the coal is spread upon the grate uniformly and frequently, whereas with hand firing coal is fed into the furnace at irregular intervals, and usually more coal is put in than is desirable to obtain a perfect combustion; moreover, each time the boiler is fired by hand the furnace doors must be opened, which allows cold air to rush in, and this current of cold air diminishes the effectiveness of the boiler.

Q. Why do mechanical stokers diminish the production of smoke?

A. Because the fuel is fed in small quantities and the motion of the grate keeps the air spaces open so that the combustion is at all times complete. As smoke is the product of imperfect combustion, it is clear that any process which makes the combustion better will diminish the amount of smoke.

Q. Why do stokers save labor?

A. Because there is no cleaning of fires or shoveling of coal or manual labor of any kind except the wheeling out of the ashes.

Q. What is the purpose of a chimney or stack?

A. Its purpose is to produce a draft that will take away from the furnaces the products of combustion and will furnish fresh air.

Q. What kinds of coal require the tallest stacks?

A. Those that do not burn very readily, such as anthracites.

Q. For what is a steam separator used?

A. In order to remove the moisture from steam before it enters the engine cylinder.

Q. For what is a steam trap used?

A. In order to remove condensed steam from steam pipes without allowing any of the steam itself to escape.

Q. If a separator or trap or heater should require cleaning or repairing, will it be necessary to shut down the plant in order to do this?

A. In a properly designed system it would not be, for they should always be piped in such a way that steam or water may, by turning the valves, be made to pass temporarily through auxiliary pipes around the heater separator or trap.

Q. Give a brief description of the manner in which a by-pass is usually constructed.

A. See "Roper's Catechism," page 173.

Q. Explain how you would proceed in cleaning a fire.

A. Let one side of the fire burn down, keeping the other side burning in good condition. Pull out the side that has burned down and knock off any clinkers that may be on the walls. Turn the good part of the fire over onto the grate bars and put on as much new fuel as it needs; allow a little time for the clinkers and ashes on the other side to cool and then pull them out.

Q. What is the purpose of a fusible plug?

A. It is intended to melt if by any chance the water falls below the level of the plug. The melting of the plug opens a passage-way by which water flows into the fire-box and extinguishes the fire.

Q. How is the plug made?

A. It is made of a brass nipple having a hexagon head on one end; this nipple is hollow and is filled with a composition which remains solid as long as the water is in contact with it, but which melts at a fairly low temperature.

Q. Where is the fusible plug usually placed?

A. In the top of a fire-box.

Q. How could you tell whether or not the fusible plug were in proper condition?

A. If it were covered with scale or soot I should not consider it were in good condition, but if free from both, I should consider it to be all right.

Q. How can you tell a high pressure from a low pressure safety valve?

A. By looking at the figures stamped on the valve or on the lever. On low pressure valves the figures will not run higher than about 30 pounds.

Q. In what way could you judge whether the safety valve of a boiler were in good condition or not?

A. If it opened always at the same pressure and never showed any indication of sticking, I should assume that it were in good condition.

Q. What is a steam damper regulator and how does it work?

A. It is an apparatus for regulating the position of the damper by the pressure of steam in the boiler. The general arrangement is to have the damper connected with a water pressure. The steam pressure in the boiler controls a valve not unlike a safety valve which admits or releases the water pressure according as the steam pressure is too high or too low.

Q. What checks have you on the accuracy of the steam gauge?

A. If the gauge reading corresponds with the position at which the safety valve blows off or with the position of the damper regulator it would show that the gauge were accurate.

Q. How can you tell whether the blow-off valve is leaking or not?

A. If it is leaking, the pipe will be hot outside of the valve.

Q. How is the feed water for a boiler regulated with a power pump?

A. By means of the by-pass on the pump.

Q. How is the feed regulated with a steam pump?

A. If the pump takes water from a water system, it is regulated by means of the throttle valve of the pump. If it takes water from a receiver into which the returns from a heating system flow together with city water, it is controlled by the cold-water valve on the receiver.

QUESTIONS FOR STATIONARY ENGINEERS.

Engineers should also be prepared to answer any of the "Questions for Firemen."

Q. What do you mean by the term "a one horse-power steam boiler"?

A. A one horse-power boiler is one which would, under ordinary conditions, supply as much steam as would be consumed in an average steam engine producing one horse-power.

Q. Is there no more definite rating than this for the horse-power of boilers?

A. Yes; generally, the horse-power of boilers is based on a capacity for evaporation of 30 pounds of water per hour from feed water at a temperature of 100° Fahr. to steam at a pressure of 70 pounds.

Q. What is this method of rating called?

A. It is known as the *Centennial Rating*, because it was determined upon by the Committee of Judges at the Centennial Exhibition in 1876.

Q. Does the horse-power of steam boilers calculated according to this rule come near to the actual consumption of steam in ordinary steam engines?

A. It is about right for an automatic cut-off, high-speed, non-condensing engine. For plain slide valve engines using a throttling governor the rating is much too low, while for compound and condensing engines it is too high.

Q. In choosing a boiler, how would you determine upon the proper size, assuming that the horse-power is based upon the Centennial Rating?

A. I would in any case have the boiler capacity somewhat in excess of that of the engine, because the evaporative power of the boiler will diminish with use owing to the accumulation of scale.

Q. Is there any disadvantage in using a boiler larger than is strictly necessary to evaporate the necessary amount of steam?

A. No; the efficiency of a boiler is not lessened by operating it below its maximum capacity, wherein the boiler differs materially from the steam engine.

Q. What horse-power boiler would you use for an automatic cut-off, single expansion, and non-condensing engine of 100 horse-power?

A. I would use a boiler of 130 to 140 horse-power based upon the Centennial Rating.

Q. Suppose the engine was used with a condenser?

A. Then a 100 horse-power boiler would be sufficient.

Q. Suppose the engine were a plain slide valve with throttling governor?

A. I would then use a boiler of 160 horse-power.

Q. Suppose the engine used was a Corliss type, non-condensing?

A. I would then use a boiler of about 100 horse-power.

Q. What is the effect on the evaporative capacity of a boiler of lowering the temperature of the feed water?

A. It diminishes the capacity of the boiler.

Q. Can a boiler of given size evaporate as many pounds of water per hour to a pressure of 100 pounds as to a pressure of 70 pounds?

A. No; it will evaporate much less water.

Q. What is meant by the evaporative efficiency of a boiler?

A. The number of pounds of steam that it will generate for each pound of fuel consumed.

Q. What evaporative efficiency would you expect from the various types of boilers?

A. From flue boilers, from 6 to 8½ pounds; from tubular boilers, from 8 to 10 pounds; from water-tube boilers, from 10 to 11 pounds of water per pound of coal.

Q. Are the average results as good as these?

A. No; they are probably 25 per cent. lower.

Q. Upon what does the grate surface in boilers depend?

A. Mostly upon the quality of coal and the draft.

Q. Is it well to have the grate surface too large?

A. No; not so large that the air passing through it will greatly exceed the amount necessary for the complete combustion of the fuel.

Q. How many pounds of coal can be consumed per square foot of grate surface?

A. From 4 to 120 pounds, depending on the coal and the draft.

Q. What do you mean by heating surface?

A. The total area of all those parts of the boiler that come in contact on one side with the flame or products of combustion, and on the other side with water or steam; that is, it is all that part of the surface through which the heat of the fire is transmitted to the water or steam.

Q. Give a rule by which you could calculate the heating surface of the cylinder boiler.

A. Multiply $\frac{2}{3}$ of the circumference of the shell in inches by its length in inches, add the area of one end expressed in square inches and divide by 144; the quotient will be the number of square feet of heating surface.

Q. How would you calculate the heating surface for horizontal tubular boilers?

A. Multiply $\frac{2}{3}$ of the circumference of the shell in inches by its length in inches; multiply the combined circumference of all the tubes in inches by the length of one of them in inches; to the sum of these two products add $\frac{2}{3}$ of the area of both tube sheets; from this sum subtract the combined area of the cross-section of all the tubes; divide the remainder by 144, and the quotient will be the number of square feet of heating surface.

Q. How much heating surface per horse-power is provided in fire- and water-tube boilers?

A. From 12 to 15 square feet.

Q. Could you then calculate approximately the horse-power of any tube boiler?

A. Yes; by calculating the heating surface in square feet and dividing it by 12.

Q. What is the average ratio between the grate surface and heating surface in stationary boilers?

A. About 35 feet of heating surface to 1 square foot of grate surface.

Q. How much good anthracite coal can be consumed per square foot of grate under ordinary conditions?

A. About 11 pounds.

Q. How much coal per horse-power per hour would you expect to be consumed if the boiler were a good water-tube boiler and the engine were a simple, high-speed, automatic cut-off engine used without a condenser? and explain how you arrive at this figure.

A. I should expect the water-tube boiler to evaporate 10 pounds of water per pound of coal; I should expect the engine, if of good size, to use about 45 pounds of water per horse-power per hour; therefore, I should expect a coal consumption of about 4½ pounds per horse-power per hour.

Q. What materials are principally used now for making boiler shells?

A. Wrought iron and steel, of which the latter is more widely used.

Q. Why is steel replacing wrought iron?

A. Because it is lighter for a given strength and therefore, since a thinner plate may be used, the efficiency of the heating surface is better.

Q. What considerations would guide you in determining upon the proper thickness of boiler plate?

A. *First*, the question of safety; *second*, durability; *third*, economy. As to safety, the thickness depends upon the quality of iron, diameter of boiler, and pressure to be carried. As to durability, the thickest metal is not necessarily the best, since the outside of the sheet becomes burned and crystallized, and in general gives less wear and satisfaction than the thinner gauge. As to economy, obviously the thinner sheets are better.

Q. Give some figures as to the range of thickness of boiler iron or steel.

A. The thickness should in general range between $\frac{5}{8}$ and $\frac{3}{16}$ of an inch.

Q. What special properties should a material possess in order to make it suitable for use in boiler plates?

A. Whether it be of iron or steel, it should have a tensile strength of not less than 50,000 pounds per square inch; it should elongate 25 per cent. without breaking, and the contraction of area of cross-section at the point where breaking takes place in the test-piece should be 50 per cent. It should also stand bending without injury around a radius equal to the thickness of the plate.

Q. What do you mean by longitudinal and curvilinear rivets?

A. By the first, I mean those that run lengthwise of the boiler; by the second, those that run around the circumference of the shell.

Q. Is the pressure on all seams the same?

A. No; on the longitudinal it is nearly double what it is on the curvilinear, and for this reason the longitudinal seams are double riveted.

Q. Does a boiler plate lose any of its strength by riveting?

A. Yes; about 45 per cent. if single riveted, and about 30 per cent. if double riveted.

Q. What determines the proper diameter for rivets?

A. The diameter of the boiler, thickness of iron, and the pressure to be carried.

Q. Give some rough figures for the diameter of rivets.

A. Rivets generally vary from $\frac{3}{8}$ to $\frac{3}{4}$ of an inch in diameter. The larger the diameter of the boiler and the thicker the plate, the greater should be the diameter of the rivet.

Q. Which is the better method of riveting boilers, by hand or by machine?

A. If thick plates, machine work is much superior, as the power of the machine brings the work together better than can be done by hand; if thin boiler plates, hand riveting answers very well.

Q. Is it better to drill rivet holes in boilers instead of punching them?

A. Very much, as the punching of holes injures the strength of the plates much more than does the process of drilling them.

Q. What is a drift pin?

A. It is a tapering steel pin, which is introduced into the holes at the seams in order to bring them into line.

Q. Is the use of the drift pin advisable?

A. No; it should be dispensed with as much as possible, as a reckless use of it often results in great injury to the boiler plates.

Q. How can its use be avoided?

A. To a great extent by the careful laying out of the holes in the sheet and drilling or punching them with good judgment; the holes will then come together so closely that they can be straightened by the use of the reamer without having recourse to the drift pin.

Q. What is the effect of hammering on the quality of iron?

A. It injures it, making it harder and more brittle.

Q. What is the effect of rolling?

A. Rolling adds to the toughness of the iron.

Q. When a boiler is under steam, is the pressure equal on all sides of the shell?

A. No; the pressure on the lower side is greater than the upper side of the boiler by the weight of the water.

Q. Is there any danger of injuring boilers by application of the cold-water or "hydrostatic" test?

A. Yes; a reckless use of this test has often resulted in injury to the boilers.

Q. Would the shell and flues be stronger under a cold-water pressure of, say, 80 pounds to the square inch than under same steam pressure?

A. No; because iron increases in strength with the increase of temperature up to about 550° Fahr.

Q. How would you calculate the safe working pressure?

A. Multiply the thickness of the shell in inches by the tensile strength in pounds per square inch; multiply one-half the diameter by the factor of safety and divide the first product by the second. and the quotient will be the safe working pressure.

Q. What factor of safety is usually employed?

A. A factor varying from 3 to 5; a safe average for stationary boilers would be 4.

Q. What value of tensile strength would be used in the rule for safe working strength?

A. That would depend upon the riveting of the joints. If single riveted, I would use about fifty-five hundredths (.55) of the ultimate breaking strength of the steel; if the joints were double jointed, I would take seventy hundredths (.70).

Q. If a boiler 48 inches in diameter were made of steel having an ultimate tensile strength of 55,000 pounds per square inch with double-riveted joints, what would be the safe working pressure if the thickness of the shell were $\frac{5}{8}$ of an inch and the factor of safety decided upon were 5?

A. $P = \frac{\frac{5}{8} \times 55{,}000 \times .70}{\frac{1}{2} \times 48 \times 5} = 200$ pounds per square inch.

Q. What materials are best adapted for the setting of boilers?

A. The walls should be of hard-burned brick laid in Portland cement; all surfaces exposed to the action of the flame or heated gases should be lined with the best quality of fire-brick laid in a thin mortar of fire clay.

Q. What should be the distance between the grate bars and the bottom of the boiler shell?

A. About 40 inches.

Q. What should be the distance between the back tube sheet and the wall?

A. For a 48-inch shell about 24 inches, and for a 72-inch shell about 36 inches.

Q. What are buckstaves?

A. They are vertical braces of cast or wrought iron, which are placed on the outside of the boiler walls and are held together at the top and bottom by tie rods. They are used to hold the boiler walls in place.

Q. What are the two styles of boiler fronts?

A. A full-flush front, which consists of a cast-iron plate covering the entire front of the setting and leaves no brickwork in sight; and the half-arch front, which covers only the furnace with an iron plate.

Q. Which of these two are the better?

A. The full-flush front.

Q. When a number of boilers are set together, is it desirable that each should be set independently from the others and that each should have its separate stack connection?

A. Yes; because each boiler can be operated and shut down independently of the others, and because the draft of one is not affected by the others.

Q. Suppose that you were asked to choose a boiler to be used where the vibration is excessive, what type of boiler would you select?

A. A locomotive or marine type of a boiler, because they require no brickwork.

Q. What are the results of the formation of scale in boilers?

A. The scale produces burning of the plates and an increased coal consumption.

Q. Why is this?

A. Because the scale is a poor conductor of heat, and therefore the water does not protect the plate against crystallization and burning, and also the heat of the fire is not imparted to the water as advantageously as if the scale were not present.

Q. Roughly, how does the conductivity of scale compare with that of iron?

A. It is about $\frac{1}{35}$ of that of iron.

Q. What are the principal ingredients contained in water that go to cause the formation of scale?

A. They are sulphate of lime, phosphate of lime, carbonate of lime, magnesia, silica, and alumina.

Q. Which is the most important of these existing in sea-water?

A. Sulphate of lime.

Q. What are boiler compounds?

A. Boiler compounds are chemical substances of various kinds that are employed in order to check the formation of scale.

Q. Will any one boiler compound be effective in all cases?

A. No; to be effective the composition of the compound must be suited to the nature of the impurities.

Q. Suppose that the principal ingredient in the water tending to produce scale were sulphate of lime, what substance would you use?

A. Carbonate of soda.

Q. What would be the best thing to do if it were found that a large amount of scale formed in boilers under your charge?

A. It would be best to have an analysis of the feed water made by a chemist, so that knowing what scale-producing substances are present we could add sufficient quantities of proper materials to change the scale producers into soluble salts.

Q. In what other way can formation of scale in boilers be largely prevented?

A. By the use of feed-water heaters and purifiers of the open type.

Q. How does this remedy the difficulty?

A. By depositing the impurities in the heater where they can do no harm, and from which they can be easily removed, instead of in the boiler itself.

Q. What do you mean by foaming in a boiler?

A. Foaming is a violent agitation of water in a boiler, which is shown by the frequent change of level of the water in the gauge glass.

Q. What are some of the causes of foaming?

A. Poor design of boiler, muddy water, foul condition of the boiler, and the presence of any soapy or greasy substance in the feed water.

Q. What injury could foaming produce on the boiler?

A. When a boiler foams badly the water is lifted from the fire surface and this allows the plates to burn.

Q. Is there any danger to the engine from foaming in the boiler?

A. Yes; mud and water are liable to be carried over with the steam into the cylinder and injure the surface of the cylinder and often cause the breaking of the cylinder head.

Q. What do you mean by priming?

A. The carrying over of water from the boiler to the engine in the form of spray.

Q. How could you detect it?

A. By noticing the exhaust from the engine; if this be white instead of colorless, it would show that moisture is present in the steam. In such cases there is generally a clicking noise in the cylinder.

Q. What causes priming?

A. Generally it is due either to the water being carried at too high a level in the boiler or to the lack of sufficient steam space.

Q. What is a safety valve?

A. A valve designed to prevent explosion of boilers by relieving them from excessive pressure.

Q. What is the general principle on which it is constructed?

A. The steam pressure is balanced by a spring or weight in such a manner that when the pressure in the boiler gets too high it overcomes the action of the spring or weight and opens a valve that allows the steam to escape.

Q. What are the most important points to be looked after in the construction of safety valves?

A. Simplicity and freedom of action.

Q. Should the stems be loose or rigid?

A. Loose, as the solid or rigid stem is liable to be jammed by the canting of the lever or weight, and in this case the higher the pressure the more difficult it is for the valve to open.

Q. What three classes of safety valves are there?

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A. The dead-weight, spring, and lever safety valves.

Q. Which are the better to use, springs or weights in safety valves?

A. This depends upon the places in which they are to be used. On vessels or locomotives, weights could not be used on account of the motion, but for stationary work, weights have the advantage in that they do not change, while springs are liable to alter their strength when under tension.

Q. How would you set a safety valve for any desired blow-off pressure in the dead-weight or spring type?

A. By adjusting the weight or the tension of the spring until this weight becomes equal to the area of the valve in square inches multiplied by the pressure in pounds per square inch.

Q. How would you calculate the weight which it would be necessary to put on the end of a certain lever safety valve for a desired blow-off pressure?

A. I would first multiply the area of the valve in square inches by the blow-off pressure in pounds per square inch and by the distance of the valve from the fulcrum in inches; then I would multiply the weight of the lever in pounds by the distance of its center of gravity from the fulcrum; then I would multiply the weight of the valve and stem by their distance from the fulcrum ; after adding the last two products together and subtracting their sum from the first product, I would divide the remainder by the length of the lever, and the quotient will be the weight in pounds required.

Q. How would you find the distance of the center of gravity from the fulcrum?

A. If the lever is of uniform cross-section, its center of gravity is at its middle point.

Q. If the lever is tapering?

A. See "Roper's Catechism," page 134.

Q. What determines the proper area of safety valves for different sized boilers?

A. They should be capable of discharging twice as much steam as corresponds with their rate of horse-power. There are many rules given—some basing it upon the heating surface, others upon the grate surface, and still others upon the coal consumption.

Q. Is one safety valve sufficient for a boiler?

A. No; it should have at least two.

Q. What do you mean by a gauge?

A. Any instrument or device used for measurement.

Q. What are the principal gauges used in connection with boilers?

A. The pressure gauge, vacuum gauge, water gauge, and salinometer gauge.

Q. What two kinds of steam gauges are there?

A. Indicating gauges and recording gauges.

Q. What is the general principle on which the indicating gauge is constructed?

A. It is usually constructed on the principle invented by Bourdon, and consists of a thin tube of elliptical cross-section bent in the form of a curve. The steam, the pressure of which is to be measured, is admitted into the tube, and its pressure tends to make the cross-section circular, which causes the tube to straighten itself partially. The tube is so connected with a pointer by gearing that the straightening moves the pointer over a suitable dial that indicates the pressure.

Q. How does the recording gauge usually differ from this?

A. It has in addition a clock that moves the dial, giving it one revolution in 24 hours, and the pointer has a pen or stylus attached that makes a complete record of the pressure during this time.

Q. Does the steam gauge register absolute pressure?

A. No; as usually constructed, it stands at zero under atmospheric pressure; therefore its pointer indicates the pressure *above* the atmosphere, or about 15 pounds less than absolute pressure.

Q. Suppose the pointer does not stand exactly at zero when there is no pressure in the boiler?

A. It should be adjusted by comparison with a standard gauge.

Q. How does a vacuum gauge differ from a pressure gauge?

A. It is made in the same way, but made to read pressure *below* the atmosphere instead of above.

Q. How are vacuum gauges generally marked?

A. So as to read in inches of mercury instead of pounds; that is to say, the readings indicate to how many inches the vacuum would allow a column of mercury to rise under atmospheric pressure.

Q. To what vacuum does an inch of mercury usually correspond?

A. To a vacuum of about one-half pound.

Q. Why are the vacuum gauges marked in this way and not in absolute pressure?

A. Because the mechanism that operates the gauge acts by virtue of the difference in pressure of the atmosphere and the vacuum chamber; therefore, as the atmospheric pressure is continually varying, the pointer would not give accurately the number of pounds of absolute pressure.

Q. What is a water gauge, and how is it usually arranged?

A. It is a device for showing the level at which the water stands in the boiler, and usually consists of a glass tube placed on the outside of the boiler with its upper end connected to the steam space and its lower end connected to the water space.

Q. What other devices are used for indicating water level?

A. Gauge cocks and safety water columns.

Q. What is a salinometer?

A. An instrument or gauge for indicating the amount of salt contained in the water used in marine boilers.

Q. What is the effect of too great a supply of air in the furnace of a boiler?

A. It diminishes the economy of the boiler, because a portion of the heat of combustion is used in heating the excess of air and this amount of heat is wasted.

Q. What are the three common methods of operating pumps?

A. By belting or gearing, by direct connection with a steam cylinder, and by electric motors.

Q. Which of these methods is usually employed for boiler-feed water pumps?

A. The second.

Q. What is a fly-wheel pump?

A. One in which the reciprocating motion of the steam piston is first converted into rotary motion by means of the crank shaft, with a fly-wheel to help it over dead centers, and then converted back into reciprocating motion for the water cylinder by another crank and rods.

Q. What is a direct-acting pump?

A. One in which the water piston is mounted on the same rod as the steam piston.

Q. What is required in order to help such a pump over the dead centers?

A. An auxiliary valve gear in addition to the main valve gear.

Q. What is a duplex pump?

A. A duplex pump is a combination of two pumps coupled together so that the steam valve of one is operated by the piston of the other, and *vice versâ.*

Q. What type of steam pump is most commonly used as a boiler-feed pump, and why?

A. The duplex pump, because it is the simplest form.

Q. What is the limit beyond which a suction pump will not lift water?

A. About 33 feet.

Q. What is the reason for this?

A. Because the pump does not actually lift the water but only creates a vacuum, allowing the water to be lifted by the pressure of the atmosphere on its surface. As the atmospheric pressure will not support the column of water more than

33 feet in height, this is the limit to the lifting of the suction pump.

Q. Is there no limit to the distance to which water can be thrown horizontally?

A. Practically none if the connections are tight.

Q. What limits the height to which a pump will force water?

A. Nothing except the power of the pump.

Q. How would you calculate the power required to pump water?

A. Multiply the number of pounds to be pumped per minute by the vertical distance in feet between the level of supply and discharge, and divide the product by 33,000. This result will be the theoretical horse-power. The actual horse-power will be obtained by adding the losses in friction corresponding to the velocity of the water. (See "Roper's Handy-Book," page 142.)

Q. Explain how you would choose the proper size of boiler-feed pump for a given boiler.

A. I would multiply the horse-power of the boiler by 30, which would give the number of pounds of water that it will evaporate per hour. I would divide this by 8.35, which gives the number of gallons; I would then choose a pump capable of supplying double this quantity, so that it would be large enough even when the boiler was being forced to its utmost.

Q. When the water is hot, what precaution must be taken with the pump?

A. It should be brass lined, so as not to corrode, and must be placed below the level of the water supply, as otherwise the hot water will not follow the plunger. A valve should also be placed between the supply and the pump, so that any accumulated vapor may be liberated.

Q. What is an injector?

A. An apparatus which forces water against a pressure by the direct action of a steam jet upon the mass of water.

Q. Give a description of an injector and how it acts.

A. There is, *first*, a steam nozzle through which the steam enters; *second*, a water-supply tube through which the water enters; *third*, a combining tube, beginning at the end of the steam nozzle where the steam and water come in contact; *fourth*, a delivery tube, from which the mixture of steam and water enters the discharge pipe. The action of the apparatus is as follows: The steam leaves the nozzle and enters the combining tube at a high velocity; owing to the friction between the steam jet and the air in the water-supply pipe, the air is exhausted from the latter, and water consequently rises owing to the pressure of the atmosphere on its surface. It enters the combining tube where it meets the steam jet and condenses it. By condensation the cross-section of the steam jet is made very small, and the entire energy due to its velocity is thus concentrated upon a very thin jet. This amount of energy is more than sufficient to force the steam into the boiler, and some of it is imparted to the water it meets in the combining tube, and the entire mixture of steam and water is carried into the delivery tube and then into the boiler by the acquired momentum.

Q. What advantages have injectors over pumps?

A. The water enters the boiler in a steady stream, and practically none of the energy of the steam used to operate it is wasted and the water enters the boiler hot; they are also more compact and have no moving parts.

Q. Is the injector more economical than a pump as a boiler feeder?

A. Not always; if the feed water used is cold, the injector is more economical, but in combination with a feed-water heater a pump is more economical.

Q. Is it desirable that a boiler plant should have both a pump and injector?

A. Yes; in case one or the other should get out of order.

Q. What is the advantage of heating feed water before it enters the boiler?

A. It increases the durability of the boiler by doing away with the strains that would be produced by the entrance of cold water. It prevents, to a large extent, the formation of scale by causing the deposition of scale-producing impurities in the heater instead of in the boiler; it produces a marked economy in the consumption of fuel by utilizing a portion of the heat in the exhaust steam that would otherwise be wasted.

Q. How much of a saving in the fuel consumption might be expected from the use of feed-water heaters?

A. About 15 per cent.

Q. To how high a temperature can the feed water be raised by a good heater?

A. There is no trouble in raising the temperature of feed water to 212° Fahr.

Q. What is the difference between open and closed feed-water heaters?

A. In the closed type of heaters the exhaust steam is not brought in contact with the water to be heated, but is carried through a series of brass tubes surrounded by the feed water; or the reverse arrangement may be used, the water being carried through the tubes and the steam passing around them. In open feed-water heaters the steam mixes with the water, the latter usually passing over a series of steel or iron pans placed in a chamber through which the exhaust steam flows.

Q. How is the pump placed in relation to the heater and boiler with open heaters?

A. The pump is placed between the heater and the boiler, and since it takes hot water, it must therefore be placed below the level of the water in the heater.

Q. What is the arrangement with closed heaters?

A. With closed heaters the water enters the pump cold and is forced through the heater into the boiler.

Q. Can an injector be used with an open heater?

A. No; because the water would be raised to such a high temperature by the heater that the injector will not work, since the injector requires moderately cold water in order to condense the steam in the combining tube.

Q. State what you consider to be the relative advantages of the two types.

A. The closed heater must be located in any convenient place, while the open heater must be placed higher than the pump that is to pump hot water. On the one hand, the open type not being under the strong steam pressure is lighter and cheaper; it is more easily cleaned; heats the water to a higher temperature; purifies it better and produces no back pressure on the engine; on the other hand, the oil from the cylinder exhaust is mixed with the feed water, and unless this is eliminated by a suitable oil separator this will injure the boiler.

Q. What is an economizer, and how is it usually constructed?

A. It is a device for heating the feed water by making use of the products of combustion after they leave the boiler and before they pass into the stack. It is usually made somewhat like a water-tube boiler out of a series of tubes connected at each end by headers. The water circulates through the tubes and the products of combustion pass around the tube and out into the stack.

Q. What fittings should an economizer have?

A. Like a water-tube boiler, it should have a blow-off pipe and a safety valve.

Q. In what cases are economizers generally used?

A. They are generally added to existing boiler plants, so as to increase their efficiency.

Q. Are they generally desirable in new installations?

A. Not if the boilers are properly designed.

Q. Can you name other methods of heating feed water than by injectors, feed-water heaters, and economizers?

A. It is sometimes heated by the use of condensers.

Q. Will the same rule that you use for calculating the boiler shells apply to the calculating of the strength of boiler flues?

A. No; because the effect of a given pressure exerted on the interior of the cylinder is not the same as if it were exerted on the outside surface. Pressure exerted within a cylindrical tube tends to make the tube assume a true cylindrical form; pressure exerted on the outside of the tube tends to crush the tube or flatten it. It is well known that iron formed into a tube would require a much greater force to tear it asunder than would be necessary to crush it.

Q. Does internal pressure cause a tearing strain or a crushing strain?

A. A tearing strain.

Q. What is a collapse?

A. It is the crushing or flattening of a flue by overpressure.

Q. How may long flues be strengthened?

A. In various ways: An early method was to rivet rings of angle- or tee-iron around the flue at fixed intervals; another method was to make the flue in sections and join these sections together by riveting on U-shaped rings; the more modern method is to make the entire flue of corrugated iron.

Q. What is the advantage of corrugating the iron of boiler flues?

A. It adds strength, facilitates expansion, and increases the heating surface.

Q. What method of strengthening the flues is employed in Galloway boilers?

A. Galloway tubes, conical in form, are placed within and across the flues and riveted to the sides.

Q. What relation exists between the length of a cylindrical tube and the pressure which will cause it to collapse?

A. The collapsing pressure is inversely proportioned to the length of the tube; that is, with a tube of double length the pressure necessary to cause collapse is only one-half.

Q. Describe the simplest form of grate.

A. A grate consists of a number of cast-iron bars shaped like beams, which are supported at each end; these bars are placed at a little distance apart, so as to allow space between them for the passage of air, the distance being from about $\frac{3}{8}$ to $\frac{5}{8}$ of an inch; the grate is placed from 2 to $2\frac{1}{2}$ feet above the bottom of the ashpit, and is inclined downward toward the bridge wall so that the fuel can be more easily distributed. The length of the grate is about 6 feet, and its width varies with the size of the boiler.

Q. Is there any fixed relation between the amount of coal consumed and the number of square feet of grate surface?

A. No; this depends entirely upon the kind of draft and the quality of coal; the consumption may be as low as 4 pounds, and in locomotive boilers with an exceedingly strong draft may run as high as 100 pounds.

Q. What would you consider a fair average for stationary boilers using anthracite coal of good quality?

A. I should consider 9 pounds per square foot per hour a fair average.

Q. Is there any rule between the grate surface and the horse-power?

A. In stationary boilers about $\frac{1}{3}$ of a square foot per horse-power is allowed, although often with particular varieties of coal better results may be obtained by changing the area of the grate and the amount of draft.

Q. What is a shaking grate, and what are its advantages?

A. It is a grate that is operated mechanically in such a way that it cleans the fires, breaks up clinkers, and removes the ashes, without the necessity of opening the fire door. As to its advantages, anything which does away with opening the fire door is desirable, since when it is open cold air rushes in and injures the efficiency of the boiler and also its durability. The shaking grate is also advantageous, in that it prevents the formation of clinkers and cleans every part of the grate, which it is impossible for the fireman to do with the slicing bar.

Q. Why does the introduction of cold air through the fire door diminish the durability of the boiler?

A. Because the cold air striking against the heated boiler plates sets up unequal strains that tend to cause leakage.

Q. What is an automatic stoker?

A. An apparatus for feeding coal into, and removing ashes from, a furnace automatically without opening the furnace doors.

Q. What are the advantages to be claimed for mechanical or automatic stokers?

A. Economy of fuel and labor and prevention of smoke.

Q. Why should stokers be productive of economy in the use of fuel?

A. Because by them the coal is spread upon the grate uniformly and in small quantities, whereas with hand firing coal is fed at irregular intervals, and more is put on than would be necessary to get the best combustion; moreover, with mechanical stokers the furnace doors need not be opened.

Q. Why do stokers lessen the smoke production?

A. For practically the same reasons; the combustion being more complete than with the hand firing, less smoke is produced.

Q. Would mechanical stokers pay in small plants?

A. No; because their additional cost and the power consumed in operating them would more than offset the saving they would produce.

Q. For what is a chimney or stack used?

A. To produce a draught that will take away from the furnace the products of combustion and will draw in fresh air for keeping up combustion.

Q. Why does a chimney produce a draught?

A. Because heated gases being less dense, the tendency of the products of combustion is to rise, and this produces a partial vacuum that is filled by the rushing of air through the furnace.

Q. On what does the amount of draught produced by a chimney depend?

A. On the height of the chimney and the difference in weight of the gases in the chimney and atmosphere.

Q. On what does this difference in weight depend?

A. Upon the temperature at which the gases leave the boiler.

Q. At what temperature do gases usually leave the boiler?

A. From 500° to 600° Fahr.

Q. On what does the area of the chimney for a given boiler depend?

A. Upon the quantity of coal to be consumed.

Q. What is the relation between the quantity of coal consumed per hour and the area of the chimney?

A. The area of the chimney in square inches should be about double the number of pounds of coal to be consumed per hour.

Q. What would be the proper area of a chimney for a 500 horse-power boiler of the water-tube type?

A. Assuming that 3 pounds of coal are used per hour for each horse-power, the total consumption of coal per hour would be 1500 pounds. The area of chimney should then be about 3000 square inches and its diameter about 60 inches.

Q. What determines the proper height for the chimney?

A. The strength of draught that is necessary for the kind of coal to be burned. Heights of chimneys based upon practical experience are given in tables in "Roper's Engineers' Handy-Book."

Q. What is a steam separator?

A. An arrangement for removing moisture from steam before it enters the engine cylinder.

Q. Why is their use desirable?

A. Because an accumulation of water in the cylinder from priming or any other cause often results in blowing out the cylinder head or steam-chest cover. Also, the presence of moisture in steam diminishes the economy in the engine.

Q. What is the general principle on which steam separators are constructed?

A. Steam enters the apparatus at a high velocity, and has its direction of flow altered or reversed so as to destroy the momentum of the particles of water in the steam. Gravity then causes these particles to fall into a passage that is provided for the purpose of receiving them. The steam freed from the water particles continues into the pipe leading to the engine.

Q. For what other purposes are separators often used?

A. To extract the oil from feed water in open heaters.

Q. What is a steam trap?

A. An apparatus for removing condensed steam from steam piping without allowing any live steam to escape.

Q. Explain the principle on which some form of trap works?

A. The trap consists of a closed vessel having an outlet that is controlled by a valve; this valve is operated by a float, and when sufficient water has condensed in the vessel to raise the float the valve is opened and a part of the water is drained off and the valve then closes. In another type the valve is operated by a bent tube of elliptical cross-section similar to that which is used in the Bourdon steam gauge; opening and closing of the valves are produced by changes in the temperature of the elliptical tube; these changes of temperature, of course, being caused by the condensation of steam.

Q. Is it necessary to shut down a plant in order to clean a separator or trap?

A. Not if the plant is properly piped, as each of these pieces of apparatus should be provided with auxiliary pipes and valves, so that steam or water may be made to pass temporarily around them.

Q. What are these auxiliary pipes and valves usually called?

A. By-passes.

Q. Give a brief description, illustrating it by a diagram, of one way in which a by-pass is usually arranged.

A. For answer, see "Roper's Catechism," page 172.

Q. Why is it always desirable to open, slowly, the valves that start an engine?

A. It diminishes the strain that would be thrown on the boiler, as the sudden vent which would be given to the steam is liable to produce strains on the boiler or to cause fluctuations of the water level. The strains that would otherwise be thrown on the engine are also avoided.

Q. In shutting down an engine, is slowness in closing the valve also desirable?

A. Yes; a sudden closing of the valve throws a pressure on the valve itself and on the pipe, and also on the boiler by suddenly checking the flow of steam.

Q. Is the use of braces in a boiler necessary?

A. It would be possible to construct boilers strong enough without the use of braces; such boilers, however, would necessarily have exceedingly thick plates and the riveting would be extra heavy, so that the first cost of the boiler would be excessive; moreover, such a boiler would not be satisfactory, as owing to the thickness of the plates they would be liable to burn out quickly. The economy of the boiler would also be poor.

Q. For what purposes are angle braces usually employed?

A. For bracing the tube sheets of boilers in the steam space.

Q. How are toggle braces usually fastened?

A. They are usually riveted in at both ends or attached to the shell by lugs; they may be adjusted by means of a swivel or turnbuckle.

Q. How would you calculate the quantity of water which a boiler will hold?

A. If the boiler is cylindrical, I would multiply the area of the head in square inches by the length of the shell in inches and divide by 1728; this will give the number of cubic feet of the water. If there are any tubes or flues, I would find their volume similarly and subtract the sum of the volumes of the tubes and flues from the total contents of the shell. The remainder when multiplied by $7\frac{1}{2}$ will give the contents of the boiler in U. S. gallons.

Q. What is the difference between a hard and soft patch?

A. A hard patch is made by taking a piece of plate and attaching it at the desired place by means of rivets and calking it in the usual manner. In a soft patch, a coating of lead or litharge is applied between the two surfaces and the patch is attached with bolts and nuts.

Q. Which is the better method of patching, and why?

A. The hard patch, because in soft patching the bolt holes being larger than the bolts the patch may be moved; moreover, the packing is not positively secure, and though the joint may be steam- and water-tight for a time, it is a point of danger.

Q. Suppose the glass water gauge should break, discharging hot water and steam into the room, what would you do?

A. I would cover one hand with a hat, cap, or other flexible covering and with the other hand would hold a coat or any piece of cloth in front of my face, and would then shut the water valve and afterward the steam valve. I would run the rest of the day by the gauge cocks, putting in a new glass water gauge as soon as possible.

Q. Suppose that a gauge cock became broken off near the boiler, what would you do?

A. I would plug up the hole with a piece of wood and use the other gauge cocks, putting in a new one as soon as possible.

Q. When a boiler is foaming, can you tell with certainty from the gauge glass or from the gauge cocks how much water it contains?

A. No.

Q. What would be the best way to find this?

A. I would shut down the engine, throw some fresh coal on the fire, shut the damper off, and open the door; the foaming will then quiet down, and the gauge glass and cocks will give nearly correct indications.

Q. What is the power of a steam engine?

A. The amount of work it will do in a certain space of time.

Q. What unit of power is used for steam engines?

A. The horse-power.

Q. What is an engine of one horse-power?

A. An engine that will do 33,000 foot-pounds per minute; that is, it will raise a weight of 33,000 pounds one foot per minute, or 550 pounds one foot per second.

Q. If a certain engine raised a weight of 66,000 pounds in half a minute, what would be its horse-power?

A. Four.

Q. What factors determine the horse-power of a steam engine?

A. Length of stroke, diameter of the cylinder, speed, and the mean effective pressure on the piston.

Q. Give the rule for calculating the horse-power of an engine.

A. Multiply the area of the piston in square inches by the mean effective pressure (in pounds per square inch); multiply the length of stroke in feet by the number of strokes (twice the number of revolutions) per minute; multiply the first product by the second and divide by 33,000.

Q. What would be the horse-power of an 18″ x 18″ engine at 100 revolutions per minute, with a mean effective pressure of 45 pounds?

A. 104 horse-power.

Q. What is a convenient formula to remember for calculating the horse-power?

A. Horse-power equals $\frac{PLAN}{33,000}$, in which

$P =$ mean effective pressure in pounds per square inch,
$L =$ length of stroke in feet,
$A =$ area of piston in square inches,
$N =$ number of strokes per minute.

Q. Having given the diameter of the cylinder, how would you calculate the area?

A. I would square the diameter and multiply by .7854, or if I had access to proper tables I could find the area from these.

Q. Explain what you mean by mean effective pressure.

A. Mean effective pressure is the average forward pressure on the piston less the back pressure.

Q. Upon what does the average forward pressure depend?

A. It depends upon the initial pressure in the cylinder and the point of cut-off.

Q. How could you find the average forward pressure in any engine?

A. By taking an indicator card of the engine, drawing several vertical lines at equal distances from each other on the card, measuring the pressure on each of these lines and taking the average of these pressures.

Q. Suppose that you had no indicator and desired to know approximately the average forward pressure?

A. If I knew the point of cut-off and had access to tables such as are found in "Roper's Engineers' Handy-Book," I could find in these tables multipliers corresponding to the point of cut-off which, if multiplied by the boiler pressure (absolute), would give the average forward pressure.

Q. What do you mean in your answer by absolute pressure?

A. The pressure above a vacuum.

Q. Is this the same as the pressure indicated by the gauge?

A. No; it is about 15 pounds more than the pressure indicated by the gauge.

Q. How would you find the mean effective pressure on the piston?

A. I would find out, as above, the absolute average forward pressure and deduct from this the absolute back pressure.

Q. What is the back pressure?

A. It is the pressure opposing the motion of the piston; in the case of engines that exhaust into the air it is about 15 pounds per square inch.

Q. What is the effect of back pressure on an engine?

A. It diminishes its power.

Q. What are used with engines to diminish the back pressure?

A. Condensers.

Q. Given the following conditions, could you calculate the horse-power of an engine?

Stroke, 12 inches;
Diameter, 12 inches;
Boiler pressure gauge, 80 pounds;
Speed counter, 300 revolutions per minute;
Back pressure gauge, 5 pounds;
Cut-off, $\frac{1}{4}$.

A. I should also need to have an indicator card or the multiplier that corresponds to a cut-off of $\frac{1}{4}$.

Q. If this multiplier is .5965, explain how you would work out the horse-power.

A. The absolute initial pressure is 80 plus 14.7, or 94.7 pounds; multiplying this by .5965 I have 56.45 as the average forward pressure. The back pressure is 5 plus 14.7, or 19.7. The mean effective pressure, therefore, is 56.45 minus 19.7, or 36.75 pounds per square inch. The area of piston is $12 \times 12 \times .7854$, or 113.1 square inches. The formula being $H.P. = \frac{PLAN}{33{,}000}$, I should have substituting figures, H. P. = 36.75 × 1 × 113.1 × 600 ÷ by 33,000, or 75 horse-power.

Q. What would have been the gain in mean effective pressure, supposing that the above engine had been used with a condenser in which there was a vacuum of 22 inches?

A. Since each inch of vacuum corresponds to about ½ pound, the back pressure would have been about 11 pounds less than the atmospheric pressure, and therefore the mean effective pressure would have been about 11 pounds greater.

Q. Is the initial pressure in the cylinder necessarily the same as the pressure in the boiler?

A. No; it is generally less for several reasons: There is a loss of pressure in the steam pipes and ports due to friction; and, further, a loss by radiation and condensation. A throttling governor or a leaky piston will also lower the pressure in the cylinder as compared to the boiler pressure.

Q. What is the common value of the steam pressure used in the cylinder of a high-pressure engine?

A. From 80 to 90 pounds.

Q. Is a pressure of 90 pounds to the square inch more economical than a pressure of, say, one-half that amount?

A. Yes; for with the lower pressure the loss by atmospheric pressure is about 15 pounds, or about one-third of the pressure on the piston, whereas with high pressure the loss due to atmospheric pressure is only about one-sixth.

Q. Is an engine larger than necessary for the work to be done economical in the use of coal?

A. No; an engine running below the load for which it was designed wastes steam. If it has a throttling governor, the steam is throttled at light loads, which reduces the pressure without doing any useful work, and this means a loss in economy; if the engine has an automatic cut-off, the expansion is increased at light loads, and this also diminishes the economy of the engine, because there is one point of cut-off that is more economical than any other and the engine is rated at this point of cut-off.

Q. Is there any power derived from the governor or fly-wheel on an engine?

A. None whatever; the governor acts merely to keep the speed of the engine constant, having much the same function as does a bridle on a horse. The fly-wheel gives out only as much power as it receives from the engine, serving merely to make the revolution more steady and to carry the engine past the dead centers.

Q. Explain the difference between a condensing and a non-condensing engine.

A. In a non-condensing engine steam after having expanded in the cylinder and done its work escapes either into the atmosphere or into a heating system; in a condensing engine the steam exhausts into a condenser where it comes in contact with some cooling substance, in consequence of which it is condensed and a partial vacuum is produced behind the piston.

Q. What is the object of condensing?

A. To do away with the back pressure on the piston, and consequently to increase the mean effective pressure and the power.

Q. In what ratio does the addition of a condenser increase the power of an engine?

A. In the same ratio which the vacuum in a condenser bears to the mean effective pressure.

Q. Suppose the mean effective pressure without the condenser was 40 pounds and the condenser had an effective vacuum of 26 inches, what would be the percentage increase in power owing to the use of the condenser?

A. Twenty-six inches correspond to 13 pounds. The increase in power is therefore $\frac{13}{40}$, or 32.5 per cent.

Q. Does it require power to operate a condenser?

A. Yes; but usually less than is gained by its use.

Q. Is there gain in economy of fuel as well as in power by the use of a condenser?

A. Yes; from 20 to 35 per cent., depending upon the size and type of engine.

Q. Why are not all engines used with condensers?

A. Because in small engines the saving is not enough to pay for the additional first cost and the increased labor and attention necessary; also the exhaust steam in many cases can be used to advantage in heating; the cost of the water for condensing might also, in some places, be greater than the saving in fuel.

Q. Roughly, how much water is required for condensing?

A. About 25 times as much as passes through the engine.

Q. What is the difference between a simple engine and a multiple expansion engine?

A. A simple engine is one in which the steam is used expansively in only one cylinder; the multiple expansion engine is one in which the steam is partially expanded in the first cylinder, and then passes into one or more other cylinders where it receives a further expansion.

Q. What are compound, triple expansion, and quadruple expansion engines?

A. A compound engine is one in which the steam expands twice; a triple expansion engine is one in which it expands three times; and a quadruple expansion engine is one in which it expands four times.

Q. What do you understand by the term "compounding"?

A. Using steam expansively in two or more cylinders.

Q. What is the object of compounding engines?

A. To obtain economy in the use of steam.

Q. What names are given to the different cylinders of multiple expansion engines?

A. The one that takes steam direct from the boiler is called the high-pressure cylinder; that one in which it expands last before passing to the atmosphere or condenser is called the low-pressure cylinder; if there are any others they are called intermediate cylinders.

Q. What is a receiver? Why is it necessary?

A. A chamber in which steam is stored after it leaves one cylinder until it is admitted into the next. It is necessary for engines the cranks of which are set at different angles. For instance, in the two-cylinder engine they would be placed at 90 degrees apart, and therefore one cylinder would not be taking steam during the time that the preceding cylinder was exhausting. Therefore a chamber is necessary to store the steam until it is wanted.

Q. What is the object of setting the cranks at different angles?

A. To secure a more uniform turning force on the crank shaft.

Q. Why does not the fly-wheel accomplish this result?

A. It does, but if it can be achieved without a fly-wheel it is better. Moreover, in marine engines a fly-wheel cannot be conveniently used.

Q. Are compound engines commonly operated with condensers?

A. Yes; it is desirable to so operate them. The low-pressure cylinders of multiple expansion engines often have a mean forward pressure of only a few pounds, or on light loads may even have a negative forward pressure which, instead of aiding the other cylinders, tends to diminish the power of the engine; therefore the use of the condenser is in such cases particularly desirable.

Q. What would you understand by the term "high-speed engine"?

A. One in which the rotative speed or number of revolutions per minute was high.

Q. What advantages do high-speed engines possess in comparison with low speed?

A. They are less expensive; are more economical to operate; run more smoothly; and they are especially adapted for driving electric machinery, which requires a high speed of rotation and a uniform angular velocity.

Q. Why should a high-speed engine cost less?

A. Because the power of an engine depends upon the area of piston, stroke, mean pressure, and speed, increasing directly in proportion to the increase in any one of these factors; therefore, by increasing the speed, any one of the other three factors may be proportionately cut down. Hence, by doubling the speed of an engine it may be built very much smaller and consequently more cheaply for a given horse-power.

Q. Why are high-speed engines more economical in the use of steam?

A. Assuming that the valve motions are equally efficient, and other things are equal in the two classes of engines, the high piston speed engine will be more economical; for one of the principal losses is due to initial condensation and evaporation in the cylinder, and this is proportionately less when more steam passes through a given cylinder in a given time. Hence the loss from this source is less in the high-speed engine than in the low-speed engine.

Q. What is an automatic cut-off engine, and how does it differ from a throttling engine?

A. An automatic cut-off engine is one the speed of which is kept constant under varying loads by a governor that changes the cut-off so that steam is admitted longer for heavy loads than for light loads. In a throttling engine the time of admission remains the same for all loads, and the initial pressure is regulated by a governor which opens and closes the throttle valve.

Q. Which is the less economical, and why?

A. The throttling engine; for when the pressure is reduced by a throttle valve the steam expands without doing useful work, and the energy represented by this expansion is wasted.

Q. Under what conditions would it be advisable to use throttling engines?

A. When the load is uniform, or nearly so, since throttling engines that use a plain slide valve are considerably simpler and cheaper to build than are automatic cut-off engines.

Q. What is the difference between single- and double-acting engines?

A. In single-acting engines steam is admitted on one side of the piston only; in double-acting engines steam is admitted first on one side of the piston and then on the other.

Q. What are the advantages of each of these types?

A. The double-acting engine, for the same diameter of cylinder, length of stroke, pressure, and speed, develops double the power of the single-acting engine. The single-acting engines, however, may be made much simpler, needing no piston-rod, cross-head, or guides. They may be run faster than the same size of double-acting engine, as the strain always acts in the same direction and as they may be readily arranged, so that the crank and the moving parts dip in oil at every revolution.

√ *Q.* What does the term "valve gear" of an engine comprise?

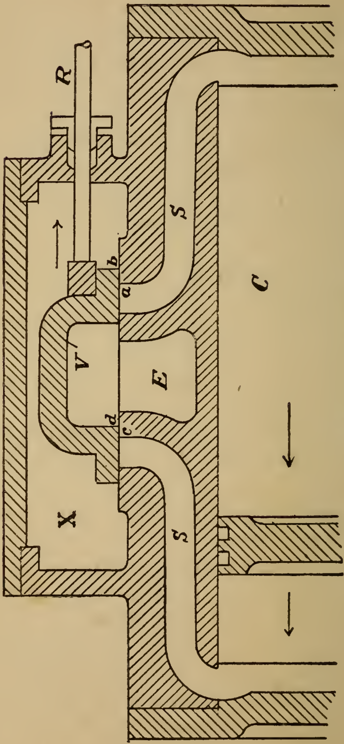
A. All the mechanism employed in distributing steam.

Q. Of what parts does the simplest form of valve gear consist?

A. Of a plain slide valve and eccentric and the necessary rods or links for transmitting the motion of the eccentric to the valve.

Q. Describe a plain slide valve and illustrate it by means of a diagram.

A. The diagram shows the valve in its central position where steam is neither being admitted to nor exhausted from the cylinder. *V* is the valve; *S S* are the steam passages through which the steam passes to the cylinder *C* from the steam chest *X*. The steam chest is always filled with live steam when the throttle valve is open. *E* is



PLAIN SLIDE VALVE.

the exhaust passage in communication with the exhaust pipe which allows the steam to pass into the atmosphere or condenser after it has done its work in the cylinder. *R* is the valve rod which derives its motion from the eccentric and imparts it to the valve.

Q. Explain the action of the valve.

A. In the position of the valve shown in the diagram, the piston is moving to the left and is nearly at the end of its stroke while the valve is moving to the right. A little farther on in its motion the valve will uncover the steam passage on the left and will admit steam behind the piston. The admission of steam will continue until on the return stroke the valve again covers the steam passage. During this period the passage on the right will have been uncovered and in communication with the exhaust chamber *E*, thus allowing steam to exhaust until this passage is again covered by the valve. After this takes place the process is reversed, steam is admitted to the right hand end of the cylinder and exhausted from the left.

Q. What are the four important events in the distribution of steam which occur in every revolution of the engine?

A. Admission, cut-off, release, and compression. Admission starts when the passage is first uncovered and continues up to the point of cut-off, which is the moment at which the passage is again covered ; release occurs when the passage is open to the exhaust chamber and continues until the passage is again closed ; compression takes place from the time of closing the exhaust passage and lasts until steam is again admitted.

Q. During what part of the process does expansion take place?

A. Expansion continues from the time of cut-off up to release.

Q. Explain the meaning of the terms lap, lead, eccentricity, travel, over-travel, and angular advance.

A. There are two laps, the outside or steam lap and the inside or exhaust lap ; when the valve is in its central position, outside lap is the distance which the outer edge of the valve extends over the outer edge of the steam passage ; inside lap is the distance which the inner edge of the valve laps over the inner edge of the steam passage. Lead is the amount of opening in the steam port at the moment at which the piston begins its stroke. If the piston begins its stroke before the steam passage is open the lead is called negative. Eccentricity or throw of the eccentric is the distance from the center of the engine shaft to the center of the eccentric. The travel of the valve is the total distance which it moves, and is equal to twice the throw of the eccentric. Over-travel is the distance which the valve travels beyond what is necessary to fully uncover the steam passage. Angular advance is the angle by which the eccentric is in advance of the position which would bring the valve in its central position with the crank on a dead center.

Q. How would you set the slide valve of an engine?

A. I would place the crank on a dead center and give the valve the necessary amount of lead, then I would turn the engine to the other dead center and see if the valve has the same amount of lead; if so, it is properly set, if not, the valve must be adjusted by means of the valve rod and nuts so as to make the leads equal.

Q. How can you find the exact dead center?

A. I would place a spirit level on the top or bottom of the stub end or connecting rod boxes, and I would move the crank up and down a little until level was shown.

Q. What is a link motion and what is its purpose?

A. A link motion consists of two eccentrics and rods, and a slotted link. It is used for reversing an engine and for varying its points of cut-off.

Q. Explain how the Stevenson link accomplishes this.

A. The two eccentrics are placed on the shaft in such a way that if the valve were operated by one the engine would move forward, and if by the other it would move backward. The link being attached to the end of the two eccentric rods receives a rocking motion. A movable block to which the valve rod is attached is carried in the slot of the link. When the block is at the end of the link nearest the forward eccentric, the engine will move forward; when the block is at the other end the engine will be reversed; as the block is moved nearer the intermediate position the travel of the valve becomes less and consequently the cut-off becomes earlier. When the block is in the central position the travel of the valve is not enough to uncover the ports, consequently the engine remains at rest.

Q. In the original form of D slide valve, what is the cause of the friction between the valve and its seat, and how can this be avoided to a great extent?

A. The friction is caused by the steam pressure which is on the back of the valve forcing it tightly against its seat. This can be avoided to a considerable extent by the use of pressure plates which relieve the back of the valve from this pressure.

Q. Is there any form of valve which is naturally balanced, and if so, is there any objection to this form?

A. Yes; the piston valve. The objection to this valve is that the seat wears uneven, and they are therefore somewhat difficult to keep tight. By proper construction the bushings which form the seat can be arranged so that they can be easily taken out and replaced.

Q. Next to the slide valve gear, what is the most common valve gear used on stationary engines, and what are the important differences between it and the plain slide valve gear?

A. The Corliss. The Corliss gear instead of the single valve which admits and exhausts steam has four independent valves which are operated by a single eccentric and wrist plate; these four valves have a partial rotation about an axis; two of them are for admission and cut-off and the other two being for release and compression. The two steam valves are connected to the wrist plate in such a way that they can be detached at any moment. This is accomplished by a tripping mechanism which is controlled by the ball governor. The cut-off is therefore under the direct control of the governor, although release and compression are constant.

Q. How does a four-valve engine differ from the slide valve and Corliss gears?

A. Like the Corliss it has four independent valves, but like the plain slide valve their motion is positive and they have no releasing mechanism; the cut-off is varied by the travel of the valve.

Q. What relative advantages have the Corliss and the four-valve types?

A. The Corliss valve gear gives a sharp and quick cut-off and wastes very little power in friction; as the valves, however, are controlled by a spring or dashpot they cannot be run at a high speed. The main advantage of the four-valve gear is that it can be run at nearly as high speed as a single valve machine, while it preserves most of the economy of the Corliss gear.

Q. What advantage have both of these gears over the single valve gears?

A. A separate passage is provided for admitting steam to the cylinder and for exhausting it, therefore, the entering steam does not, as in the single valve gear, come in contact with comparatively cold walls; consequently there is much less loss by condensation, and these two gears are much more economical in the use of steam.

Q. Suppose the slide valve becomes leaky from wear, what would you do?

A. I would take it out, have its face planed, and the seat filed and scraped.

Q. What is a rotary valve?

A. A valve which has a revolving motion.

Q. What is a semi-rotary valve?

A. A valve which has a motion of revolution, but which does not make a complete revolution; as, for example, the Corliss valve.

Q. What is a gridiron valve?

A. A valve with several small narrow openings in it, and having very much the appearance of the kitchen utensil of that name.

Q. Is the cut-off produced by the link motion capable of producing as satisfactory results as the automatic cut-off?

A. No; because in the case of the link varying the cut-off also varies the lead.

Q. What is an eccentric?

A. It is a device used to take the place of a crank, and consists of a circular disc and surrounded by a strap which turns freely on it; the center of the disc is somewhat off the center of the shaft on which the eccentric is mounted.

Q. What are the chief methods used for governing the speed of stationary engines?

A. Varying the initial pressure in the cylinder to suit the load by means of the centrifugal governor actuating or throttling valve, and varying the point of cut-off by means of a governor actuating the valve gear.

Q. Which is the better method, and why?

A. Varying the point of cut-off, because it gives closer regulation and greater economy in the use of steam. It is also much less liable to cause knocking under very light loads.

Q. In setting the valves of an engine, is there any difference in the leads given at the two ends?

A. Yes; a little more lead is given at the crank end of the cylinder in order to make up for the difference in the area of the two sides of the piston due to the piston rod, and also to allow for the shortening of the valve motion on that side as wear is taken up.

Q. Suppose that the nuts which hold the valve on the stem should work loose, what would you do?

A. I would set the engine on the dead center, head end, and after taking the steam chest cover off would adjust the nuts so that the valve showed a little lead at the head end; then I would turn the engine to the other center, and if the proper amount of lead showed there the valve would be all right; if not, I would, by adjusting nuts, give the proper amount of lead and then put on the steam chest cover.

Q. Explain in detail how you would set the valves on a Corliss engine of the so-called crab-claw type.

A. See that the governor is on the safety-pin and take off the hook rod from the wrist plate.

Adjust the dashpot rods and reach rods so that the wrist plate may be turned through its entire travel, taking up the steam valves but without releasing them ; next, take out the safety-pin, letting the governor down and again move the wrist plate ; in this case the safeties on the releasing cams should keep the crabs down so that they will not touch the blocks on the bell cranks and will, therefore, not open the steam valves. Next, turn the wrist plate into its central position and adjust the connections between the plate and the exhaust valves so that the edges of the ports and the valves correspond ; adjust the connections between the wrist plate and steam valves so as to give the proper amount of lead (about one-quarter inch), turn the eccentric until the rocker arm is vertical and adjust it so that the wrist plate will be central. Next, adjust the eccentric rod by turning the eccentric shaft to a dead center and adjust the length of the rod so that the travel mark in this direction just corresponds with the center mark ; then turn the eccentric to the other dead center and see if the other travel mark corresponds with the center mark. If so, the rod is properly adjusted. Next, put the engine on its head end center and turn the eccentric so as to give the proper lead and make it fast; then turn the engine to the other center, and if you have the same lead the adjustment is correct. Now put the governor in its running position, turn the engine over and adjust the rods so as to give equal cut-off.

Q. At what cut-off is the Corliss engine usually run?

A. About one-quarter stroke.

Q. How late can the cut-off be made?

A. Not more than half stroke.

Q. In case the lead of the valves at the two ends were different, what might cause this?

A. The eccentric rod might be either too long or too short. If it were too long it would show too much lead on the crank end, and if too short it would show too much lead on the head end.

Q. How can the point of cut-off be lengthened on the Corliss valve gear?

A. By lengthening the head end reach rod or shortening the crank end rod.

Q. Does a Corliss require as much compression as a high-speed engine of the same size, and why?

A. No, because it does not run as fast; therefore, the moving parts have not the same amount of energy stored in them, and hence do not need so much of an air cushion in the cylinder at the end of the stroke.

Q. If you wish to make a Corliss engine do more work without increasing the boiler pressure or altering the speed, how could you do this?

A. Decrease the lap of the steam valve and turn the eccentric back proportionately.

Q. In what ways may a governor be made to vary the cut-off?

A. By a releasing mechanism as with the Corliss valve gear, by the action of the ball governor on the block of a link, and by a shaft governor.

Q. Describe a shaft governor and its method of action.

A. In the shaft governor one or more weights are placed in the fly-wheel, and the centrifugal force of these weights is balanced against one or more springs. The weights are attached to pivoted arms, and these arms are connected to the eccentric actuating the valve gear. The action of the governor is as follows: When the speed increases, the centrifugal force on the weights tends to move them away from the shaft, and their motion is transmitted through pivoted arms so as to alter the position of the eccentric, varying either its angular advance or both, and in this way shortening the cut-off.

Q. What difference does it make on the distribution of steam, whether the cut-off be varied by altering the angular advance or by changing the throw of the eccentric?

A. Changing the angular advance increases the lead at the same time as it decreases the cut-off.

When the throw of the eccentric is changed the reverse action takes place.

Q. What method then should you consider the best for varying the cut-off?

A. A method in which both the throw of the eccentric and angular advances are changed by the governor.

Q. Having given the number of revolutions of the ball governor and the diameter of the engine pulley, how would you find the diameter of the governor shaft pulley?

A. I would multiply the diameter of the engine pulley by the number of revolutions and would divide the product by the number of revolutions of the governor.

Q. Having given the number of revolutions which the governor is to make and the diameter of the governor shaft pulley, how would you calculate the proper diameter of the pulley to be placed on the engine shaft to operate the governor?

A. I would multiply the number of revolutions of the governor by the diameter of its pulley and divide the product by the number of revolutions of the engine.

Q. What do you consider the best material for the foundation of machines?

A. Hard-burned brick laid in Portland cement.

Q. Cannot satisfactory foundations be made of concrete?

A. Yes; if the work is carefully done the foundation will be quite as good, but I believe that there is a greater risk of careless work in the concrete foundations than in the brick.

Q. What determines the proper depth for foundations?

A. The size of the engine and character of the ground. They should always be carried deep enough so as to rest on solid ground. If the ground at the surface is sufficiently solid, no greater depth need be used than would give sufficient weight for the foundation to hold the engine down and to take up the vibrations of the engine.

Q. How would you proceed to start an engine?

A. I would first see that all the drips were open; I would then slightly open the throttle valve and warm the cylinder up gradually; then I would open the valve still further and start the engine slowly, gradually bringing the engine up to speed; and after it becomes thoroughly warmed up I would close the drips.

Q. Suppose you had a Corliss engine and the main valve on the engine was broken, how could you stop the engine?

A. I would throw the eccentric hook out of gear and stop by means of the starting bar.

Q. Suppose you discovered that the cylinder was worn hollow in the middle, what would you do?

A. I would have it rebored.

Q. In case the crank or wrist pin should be cut or worn oval, how would you proceed?

A. I would caliper them and file them round.

Q. If the shoes in the cross-head guides become worn, what would you do?

A. I would put liners between the back of the shoe and the cross-head, or would replace them with a new set of shoes.

Q. In case the eccentric slipped or turned on the shaft so as to stop the engine, what would you do?

A. I would put the engine on the center, take off the bonnet of the steam chest and move the eccentric round in the direction in which it used to run until the valve had the proper lead; I would then fasten the eccentric securely in place with the seat screw or a key.

Q. Suppose the eccentric should become worn flat at two points, in the direction of push and pull, what course would you adopt to remedy the difficulty?

A. I would file it down to the smallest diameter of the worn part.

Q. For the lubrication of the engine or any other piece of machinery, how much oil is it advisable to use?

A. No more than is absolutely necessary to keep the bearings reasonably cool. The use of an excessive amount of oil is not only costly but increases an accumulation of gum and dirt in the bearings.

Q. Suppose that any bearings of the engine should heat, what would you do?

A. I would first examine the oil cups to see if the bearings were getting the proper amount of oil. If they were and the bearings were new, I would cool them temporarily by surrounding them with ice, or if possible, of course I would stop the engine and try to find out what was the cause. If the appearance of the bearings were smooth and uniform, I would try to loosen them a very little at a time; if this did not remedy the trouble, I should consider that the bearings were out of line and would reline them. If the bearings are dirty from an accumulation of gum, I would clean them with strong lye and oil while the engine is in motion. A mixture of flour of sulphur and oil is often effective in stopping the heating of bearings.

Q. When an engine is stopped, how should the cylinder drips be left?

A. They should be left open so as to allow the condensed steam to escape.

Q. Explain how you would pack a stuffing box.

A. I would first remove all the old packing and clean out the box, then cut the new packing to the proper length and put it in place, having the joints at opposite sides of the box; I would then screw up the stuffing box just far enough to stop the leakage. If it is screwed up too tight, the power of the engine will be diminished and the packing will be quickly worn away. The packing should, of course, be perfectly free from dust or grit.

Q. Suppose that a packing in the piston becomes loose, what would be the effect?

A. Steam would leak past the piston, materially cutting down the power of the engine and wasting coal.

Q. How often should a piston be examined?

A. Two or three times a year at least, and, of course, at any time when it is suspected that the packing or rings need looking after.

Q. What should be done supposing that the joints between the rings and the head are corroded?

A. They should be ground with emery and oil, or if badly corroded, should of course be faced up in a lathe.

Q. What would be the effect of screwing down the packing of the spindle of a ball governor too tightly?

A. It would interfere with the free movement of the governor and cause the engine to regulate badly.

Q. Suppose that you heard a creaking noise in the cylinder, to what would you suspect this were due and what would you do to remedy it?

A. I should suspect the presence of moisture in the cylinder, and I would open the cylinder drip-cocks.

Q. What are some of the causes of knocking in engines, and how would you proceed to remedy the various cases?

A. Knocking may be due to a great variety of causes. One is lost motion in the boxes either of the cross-head, crank pin or pillow blocks, or to a looseness of the key holding the piston rod in the cross-head. To stop it, of course, the lost motion should be taken up either by means of the key or by filing the edges of the boxes. Knocking may be due to the wrist of the cross-head or crank pin being worn out of round. In this case the crank or wrist pin should be turned up. If the knocking is caused by the engines being out of line, the remedy would be, of course, to line up the engine exactly. Often it is caused by the packing around the piston rod being too tight. To remedy the trouble, take out the old packing and put in new, screwing it up no tighter than is necessary to just prevent the escape of steam. Sometimes knocking is caused by lost motion in the adjustment between the valve and the valve rod; in this case remove the cover of the steam chest and adjust the jam-nuts on the valve rod. If, as is sometimes the case, knocking is caused by the crank being ahead of the steam, the trouble will be removed by moving the eccentric forward so as to give more lead to the valve. The knocking may, however, be caused by too much lead, in which case the eccentric should be moved back. Knocking may be caused by the too early closing of the exhaust; in this case the exhaust chamber in the valve should be enlarged. Sometimes there is too little clearance between the piston and the cylinder head, in which case the cylinder head should be turned off a little on the inside. It has happened that too little counter-bore in the cylinder produced knocking, because the piston rings wore a shoulder at the ends of the cylinder and when the keys or packing rings were set out the edges struck these shoulders and caused the knock. In this case the remedy is to counter-bore the cylinder again. A somewhat similar trouble occurs on the ends of the guides; shoulders are worn in them and produce knocking—the remedy in this case, of course, is to replane the guides. Knocking is also caused by a loose follower plate. In this case the trouble is obviated by bringing the bolts up tight.

Q. What does a steam-engine indicator do?

A. It records the pressure in the steam cylinder at every part of the stroke.

Q. Describe briefly its construction.

A. The indicator consists of a small cylinder, which contains a piston, the rod of which is enclosed in a spiral spring which opposes the motion of the piston. The piston rod after passing through the top cylinder cover is attached by means of a parallel motion to a pencil on the end of a long, light lever. This pencil moves in a vertical straight line whenever the piston moves. Another cylinder with an axis parallel to the first carries a paper drum, and this drum is attached by means of a cord and a reducing motion to the cross-head of the engine, so that the movement of the drum is proportional to the movement of the cross-head. When the little cylinder of the indicator is shut off from connection with the main steam cylinder by a cock, the pencil when held against the drum makes a horizontal line. If now the cock be opened, thus admitting to the little cylinder of the indicator the same pressure that exists in the main cylinder, the pencil will trace a figure, every point of which is at a height from the horizontal proportional to the number of pounds pressure in the main cylinder at that point of the stroke.

Q. What is the *atmospheric line* in the indicator diagram?

A. It is the horizontal line drawn by the pencil when the little cylinder of the indicator is open to the atmosphere.

Q. What things about an engine can you ascertain by taking an indicator diagram?

A. First, the forward pressure of the piston and the back pressure at every point in the stroke, from which can be calculated the average forward and average back pressure and the mean effective pressure on the piston. *Second*, the power of the engine under all conditions, if in addition to taking the indicator diagram we know also the speed. *Third*, the diagram shows when steam is admitted, cut off, exhausted, and compressed, and therefore shows whether the valves are properly set.

Q. Explain how you would calculate the mean effective pressure from an indicator card, and state what you would need to know.

A. I would need to know the scale of the spring. I would draw a vertical line at each end of the diagram, then I would draw 20 vertical lines parallel to this, dividing the card into equal spaces, except the first and last spaces which would be one-half size. Then on these verticals I would measure the length between the back pressure line and the forward pressure line, and mark each length on a long strip of paper. The sum of all these lengths I would divide by 20, which would give the average length of ordinates, and these multiplied by the scale of the spring will give the mean effective pressure.

Q. Is the power furnished by the crank end of the engine the same as that furnished by the head end, assuming that the indicator cards are exactly alike?

A. No; while the mean effective pressure would be the same the area of the crank end of the piston is not all effective since steam does not press on that portion of the piston to which the piston rod is attached; therefore, in calculating the power of the crank end the area of the piston rod should be subtracted from the area of the piston, and the difference between the two areas should be used in the formula for horse-power.

Q. For what is a condenser used?

A. A condenser is used to condense steam exhausted from an engine so as to reduce the back pressure against which the engine is working.

Q. What effect has the condenser on the power of a given engine?

A. It increases the power of the engine from 20 to 30 per cent.

Q. What are the principal types of condensers used?

A. There are two types—jet condensers and surface condensers.

Q. What is the difference between the two types?

A. In jet condensers the steam to be condensed comes in contact in the condenser pump with the condensing water; in surface condensers the steam and condensing water do not mix, one of them being in a series of tubes and the other being in a vessel surrounding the tubes.

Q. What are the advantages of the two types?

A. Surface condensers have the advantage for use on shipboard, since the condensed steam not coming in contact with the salt condensing water it may be used again in the boilers. Steam of any pressure may be condensed and the vacuum is usually higher than in jet condensers; they are much more expensive, however, and are more liable to have their vacuum impaired by the leaking of tubes.

Q. Can a surface condenser be converted into a jet condenser and *vice versâ?*

A. The surface condenser can be used as a jet condenser by admitting the steam and injection water into the same chamber; but a jet condenser cannot be used, of course, as a surface condenser.

Q. At what temperature does a jet condenser work best?

A. At about 100° Fahr.

Q. What vacuum can be obtained in a good condenser?

A. Up to about 26 inches.

LESS PRACTICAL QUESTIONS.

Q. What is power? What is the unit of power?

A. Power is the rate of doing work; that is to say, the number of foot-pounds of work done per minute. The ordinary unit of power is the horse-power, which is a rate of doing work equal to 33,000 foot-pounds per minute.

Q. Suppose that a pump raises 66,000 pounds of water four feet and the time required for doing it is two minutes, what is the horse-power?

A. The horse-power $= \frac{66,000 \times 4}{33,000 \times 2} = 4$ H. P.

Q. What is the rule for obtaining the horse-power in any given case?

A. Multiply the number of the pounds raised by the number of feet which it is raised, and divide by the number of minutes which it takes to do the work. Divide further by 33,000 and the result is the number of horse-power.

Q. How could you measure the power required by a certain machine if it were driven either direct from an engine or from a shaft which receives power from an engine?

A. I would indicate the engine with the machine running, and calculate the power from the indicator card; I would then stop the machine and indicate the engine again and calculate the power from the card. The difference between the two powers will be practically the power required for operating the machine.

Q. Suppose that the machine, instead of being driven by an engine, were operated by an electric motor, could you measure the power, and if so, what instruments would you require and how would you proceed?

A. Yes; if I had the proper instrument. I should need an ammeter and voltmeter of suitable range. I would measure the current with the ammeter by connecting it so that the main current passed through the instrument, and I would measure the voltage of the motor by connecting the voltmeter across the brushes. If the motor is a direct current motor the products of the volts and the current divided by 746 will give the horsepower.

Q. How would you calculate the weight which can be lifted with a lever by the application of a certain force at one end of the lever?

A. Multiply the applied force by the distance from its point of application to the fulcrum, and divide this product by the distance from the fulcrum to the weight to be lifted. The quotient will be the weight which can be lifted.

Q. What is heat, and how does it differ from temperature?

A. Heat is a form of energy, while temperature is a measure not of the heat in a body, but of the tendency of that body to give up its heat to other bodies.

Q. So far as the engineer is concerned, how is heat generally produced?

A. By the combustion of fuel in the furnace of the boiler; the combustion being due to a combination of the oxygen in the air with the constituents of the fuel.

Q. Describe the instrument with which temperature is measured.

A. Temperature is measured by means of a thermometer, which consists in its ordinary form of a small hollow glass tube with a bulb at its bottom. After the air has been exhausted from the tube it is partially filled with mercury and the upper end is sealed. Then, either the tube itself is graduated or it is placed in a case which has graduations by which the height of mercury in the tube can be read. Whenever the instrument is heated the mercury column rises owing to the expansion of mercury in the bulb, but when it is cooled the opposite action takes place.

Q. How are the graduations made in the ordinary Fahrenheit thermometers?

A. The instrument is placed in melting ice and the position of the mercury column marked 32°; it is then placed in boiling water at atmospheric pressure and the new position of the mercury marked 212. The distance between the two marks is divided into 180 equal parts called degrees.

Q. What other thermometers are used besides the Fahrenheit?

A. The Centigrade and Reaumur.

Q. What is the difference between the Centigrade and the Fahrenheit scale?

A. In the Centigrade the point at which mercury stands when the thermometer is placed in melting ice is marked zero; and the point for boiling water is marked 100. The distance between the two parts is divided into 100 equal parts.

Q. What is the unit of heat?

A. The unit of heat is the amount of heat which will be able to raise the temperature of 1 pound of water 1 degree.

Q. What is the "specific heat" of any substance?

A. It is the number of heat-units necessary to raise the temperature of 1 pound of it 1 degree.

Q. Is there any relation between units of heat and units of work?

A. One heat-unit equals 778 units of work (foot-pound).

Q. What is latent heat?

A. Latent heat is heat absorbed by a body when it changes its physical state. For instance, when it changes from a solid to a fluid state, as from ice to water, the heat absorbed is called the latent heat of liquefaction. The heat absorbed in changing from water to steam is called the latent heat of vaporization.

Q. In what ways is heat transferred from one body to another?

A. It is transferred by radiation, conduction, and convection.

Q. In a boiler, how is it transferred from the fire to the steam?

A. By conduction in the iron, and from the iron to the particles of water touching the iron; it is then transferred from these particles to the others by conduction and convection.

Q. What substances are in general the best conductors of heat?

A. The metals.

Q. What kind of substances radiate heat best?

A. Substances of dark color with roughened surfaces.

Q. Why are the coverings of steam pipes painted white?

A. Because we desire to have as little heat as possible radiated from the pipes, and white radiates less than dark colors.

Q. Why should a bare copper pipe carrying steam be kept brightly polished?

A. Because if allowed to become dull more heat would be radiated.

Q. What are some of the best non-conductors of heat?

A. Magnesia, mineral wool, hair felt, and cork.

Q. What would be the objection to leaving steam pipes bare?

A. There would be a waste of fuel caused by loss of heat, which is radiated from the pipes; there would be a loss of pressure in the steam and a condensation of steam into water, which, if carried over into the engine, would be liable to give trouble.

Q. How many pounds of air will be required to burn a pound of coal?

A. About 12 pounds.

Q. What is the cause of smoke?

A. Smoke is caused by imperfect combustion of the fuel; the black appearance being due to the presence of small unburned particles hanging suspended in the air.

Q. What are some of the principal fuels used in making steam?

A. Coal, coke, wood, petroleum, and gas.

Q. What are the chief constituents of coal?

A. Carbon is the chief constituent. Coal also contains hydrogen and nitrogen and sulphur, together with the constituents forming the ash.

Q. How many heat-units are produced by the complete combustion of one pound of good coal?

A. About 13,000.

Q. What is the difference between anthracite and bituminous coal?

A. Anthracite is nearly all carbon, while bituminous coal has a large percentage of other materials.

Q. How many pounds of wood (roughly) are needed to produce as much heat as a pound of coal?

A. About $2\frac{1}{2}$ pounds.

Q. How great an evaporation per pound of coal can be obtained practically?

A. About 11 pounds.

Q. What proportion does the ash bear to the amount of fuel?

A. The ash will vary anywhere from 1 to 30 per cent. of the amount of fuel.

Q. Of what is the atmosphere composed?

A. Of a mixture of about one part (by volume) of oxygen to four parts nitrogen.

Q. Does air have weight?

A. Yes; a weight per cubic foot varying with the pressure.

Q. To what is the atmospheric pressure, so-called, due?

A. It is due to the pressure which the air exerts on all bodies by virtue of its weight. As the atmosphere extends to a distance of some forty-five miles from the earth's surface, every square inch is subjected to a pressure equal to the weight of a column of air one square inch cross-section and some forty-five miles long.

Q. How does the weight per cubic foot compare with that of steam at atmospheric pressure?

A. The weight of air is about double the weight of steam.

Q. What is the effect of the application of heat to air?

A. It expands the air $\frac{1}{492}$ of its volume for each degree rise in temperature.

Q. How much is the pressure of the atmosphere at sea level?

A. About 14.7 pounds per square inch.

Q. What instrument is used to measure atmospheric pressure?

A. The barometer.

Q. Will the barometer read higher on a mountain or at the sea level?

A. It will read higher at the sea level, because the mercury column is forced up by the weight of a longer column of air.

Q. Will water boil at the same temperature on a mountain as at sea level?

A. No; it boils at a lower temperature on a mountain, because the pressure of the atmosphere which tends to prevent the steam from rising from the surface of the water is less on a mountain than at sea level.

Q. What is the composition of water?

A. Water is composed of about eight parts, by weight, of oxygen to eleven parts of hydrogen.

Q. What is the weight per cubic foot of water?

A. The weight per cubic foot of moderately pure water is about 62.5 pounds. Impurities in the water will increase its weight so that sea water is much heavier than fresh water.

Q. In what three physical states or forms does water exist?

A. In the form of ice, water, and steam.

Q. What is necessary to change from one form to the other?

A. We can change the physical state of water by either applying or withdrawing heat from it.

Q. At what temperature does water boil?

A. This depends upon its purity and the pressure acting upon it. Pure water at sea level boils at 212° Fahr.

Q. Is the boiling-point of salt water the same as that of fresh?

A. No; it is higher.

Q. What is the weight of a cubic foot of ice?

A. About 57 pounds.

Q. How many units of heat are necessary to change a pound of ice into water?

A. About 142.

Q. What is the scientific name given to this number?

A. The latent heat of liquefaction.

Q. How many heat-units are necessary to convert a pound of water into steam?

A. At atmospheric pressure, about 965.

Q. How many cubic inches of water are there in a gallon?

A. In the standard U. S. gallon, 231.

Q. What would be the pressure per square inch produced by a column of water 10 feet high? Explain how you would calculate this.

A. A cubic foot of water weighs 62.5 pounds, therefore a cubic inch weighs 62.5 divided by 1728. A column of water 12 inches high and one square inch cross-section would weigh 12 times this amount, or .434 pound. Therefore, the pressure produced by the column 10 feet high would be .434 times 10, or 4.34 pounds per square inch.

Q. What is the difference between "hard" and "soft" water?

A. "Hard" water is water that holds mineral salts in solution. "Soft" water is water that is practically free from impurities.

Q. What do you understand by the term "head" applied to water?

A. I understand a difference in level or the pressure due to that difference in level.

Q. What is steam?

A. Steam is the gaseous form of water, and is produced from water by the action of heat.

Q. Can you see steam?

A. No; steam itself is invisible, being, like air, without color. If, however, a jet of steam be allowed to flow into the air it will form a cloud; this cloud is not the steam itself, but is produced by water particles condensed from the steam.

Q. What is the relative volume of space occupied by steam and by the water from which it is produced?

A. At atmospheric pressure a cubic inch of water when changed into steam will occupy a space of about one cubic foot. Of course, if the steam is subjected to a greater pressure its volume will become proportionately less.

Q. What is superheated steam?

A. It is ordinary dry steam, which, after being removed from contact with the water from which it is produced, is raised by the application of heat to a higher temperature.

Q. Is there any relation between the pressure of steam and its temperature?

A. Yes; a certain temperature always corresponds to a certain pressure. The actual values of pressure and temperature are given in steam tables.

Q. What is the temperature of steam at 60 pounds gauge pressure; 100 pounds; and 135 pounds?

A. 307°, 337°, and 358°, respectively.

Q. In the steam tables, what is the meaning of latent heat of vaporization?

A. The number given in the tables in the column under latent heat means the number of units of heat which must be applied to a pound of water at the corresponding pressure in order to change it into steam at that pressure.

Q. When a pound of steam at a temperature of 100 pounds gauge pressure condenses, how much heat is given off?

A. In condensing it gives up a number of heat-units equal to the latent heat of steam at that pressure. During this process the temperature of the steam does not change.

Q. After all the steam is condensed into water, suppose that the water cools to a lower temperature, how much heat is given off?

A. The number of heat-units given off will be equal to the heat of the liquid (or sensible heat) at the higher temperature less that at the lower temperature.

Q. What is the weight of a cubic foot of steam?

A. This depends entirely upon its pressure. At atmospheric pressure the steam from a cubic inch of water occupies about one cubic space, so that its weight per cubic foot would be about $\frac{1}{1700}$ of the weight of water. The weight of the cubic foot of water being 62.5 pounds, the weight of a cubic foot of steam at atmospheric pressure will be found by dividing 62.5 by 1700.

Q. If you put a thermometer first in the steam space of a boiler and next in the water space, will its readings be any different in the two places?

A. No; the temperature of water and of steam in contact with it is always the same.

Q. What is the specific gravity of a substance?

A. The ratio of its weight to an equal bulk of water.

Q. What is the difference between cast and wrought iron?

A. Cast iron is less pure, and contains carbon and other impurities. It has a crystalline structure and cannot be hammered or drawn out like wrought iron.

Q. What is steel?

A. Steel is a modification of iron produced by mixing with it a small percentage of carbon;

the amount of carbon being determined by the special properties which it is desired to produce in the steel.

Q. What is the effect of heat on iron or steel?

A. It expands it, and up to a certain point (about 600° Fahr.) increases its strength somewhat.

Q. What is brass?

A. Brass is an alloy of copper and zinc in various proportions.

Q. What is bronze?

A. Bronze is an alloy of copper and tin.

Q. What do you understand by the term "tensile strength" of a material?

A. I understand the number of pounds of pull that must be exerted on a piece with one square inch cross-section in order to rupture the piece.

Q. What do you understand by the term "compressive strength," and what other expression is often used?

A. The expression "crushing strength" is often used. The crushing strength is the number of pounds per square inch that must be applied in order to crush the material under test.

Q. What is the tensile strength of cast iron, approximately, and what is its crushing strength?

A. Tensile strength, about 16,000 pounds per square inch; crushing strength, about 100,000.

Q. What are the tensile and compressive strengths of wrought iron?

A. They are nearly equal to each other, being about 50,000 pounds per square inch.

Q. What is the strength of steel?

A. The strength of steel varies very greatly according to its composition. Mild steels low in carbon have a strength of about 50,000 pounds. Steels high in carbon may have a strength as high as 200,000 pounds per square inch.

STEAM HEATING.

Q. What are the two principal systems of steam heating in use at the present day?

A. The gravity and the reducing systems.

Q. What are the distinguishing features of the gravity system?

A. The boiler is placed below the level of any radiator. Steam is generated at a pressure rarely exceeding ten pounds and is carried to the radiators through a supply main and branches. From the other end of the radiator a branch connects to a return main, which carries the water of condensation back to a low point in the water space of the boiler.

In this system the circulation or return flow of water to the boiler is produced by gravity alone.

Q. What are the advantages of this system?

A. Its chief advantages are its simplicity, ease of operation, and cheapness in first cost. It is as economical, in fact more so, considered simply from the heating standpoint, although when the heating system is auxiliary to a power plant the reducing system may be cheaper in operation.

Q. What are the necessary valves in the gravity system?

A. A stop valve in the riser near the boiler, and a stop and check valve in the return pipe, where it enters the boilers with the stop valve nearest the boiler, and a blow-off valve.

Q. What other fittings should a boiler have?

A. Safety valve, pressure gauge, gauge cocks, and water gauge glass.

Q. In this system, how do we get the extra supply of feed-water that will be required on account of leakage or waste?

A. The boiler is connected to the city mains through a valve.

Q. Is a pump, inspirator, or injector necessary?

A. No; because the pressure used is so low that the city pressure is always sufficient to force water into the boiler.

Q. When put in charge of a boiler, what would you do in order to find out whether or not it were in good working condition?

A. Examine the fittings of the boiler and see that the stop valves are closed. Turn on city pressure (if this pressure is higher than the safe working pressure of the boiler, the feed valve must be kept sufficiently closed to prevent the pressure on the boiler from rising to a dangerous point) and notice if the reading of the gauge corresponds with the pressure at which the safety valve blows. Open the gauge cocks and let the boiler gradually fill. When the water gets high enough try the water-gauge cock. Fill the boiler completely, closing the cocks and safety valve, and turn the city connection until the gauge shows a pressure a little less than the blow-off pressure. Then examine carefully all accessible parts of the boiler to see if there is any leakage.

Q. Explain what is the proper method of starting up when the boiler has been out of use and contains no water.

A. Fill the boiler with water to second gauge cock and open the steam stop valve. Start a fire slowly so that the water and boiler may be heated gradually and evenly in order to avoid strains from unequal expansion. As soon as the pressure gauge shows one or two pounds examine all pipe and the radiators for leaks. These being tight the steam may be raised to the desired pressure.

Q. Explain what should be done when a boiler is to be shut down for the summer.

A. Let the fire go out and allow the boiler to cool for several hours, then open the blow-off valve and let all water drain from the boiler; at the same time allow air to enter the boiler through cocks or safety valve. Open all jet- and drip-cocks in order to drain any water that may have collected in the fittings or connections. Finally, clean the boiler of all dirt and ashes.

Q. What would you do if at any time a serious leak should occur in the mains or radiators?

A. If the leak were in a radiator I would shut it off by closing its two valves. If, however, the leak were in the mains or branch connections, I would shut off both stop valves and draw the fire.

Q. What are the important features of the reducing system of steam heating?

A. Steam is generated at a high pressure for power purposes. This steam is afterward reduced to a low pressure by passing it through a reducing valve.

The steam condensed in the radiators passes through the return pipe into a trap, and from the trap to a receiver tank or hot well, from which it is forced into the boiler by a pump or injector.

Q. What is the purpose of the trap?

A. To take the water of condensation from the pipe without letting any of the steam escape.

Q. In a system where steam is carried to the top of the building and then distributed to the radiators through vertical risers, where is it desirable to place an auxiliary trap, and why?

A. There should be a trap to take the drip from the bottom of all the supply risers in order to keep these risers free from water of condensation, which would impair the circulation of steam.

Q. What is a reducing valve?

A. It is a valve for lowering the pressure of steam.

Q. Describe any forms of reducing valve with which you are familiar.

A. In one variety the valve is of the piston type and is pressed upward by the low pressure steam and downward by a lever and weight. High pressure steam is in an annular chamber surrounding the hollow piston. When the pressure in the heating system falls below that for which the weight is set the piston is forced downward. This movement opens a series of small ports by which the live steam passes through the hollow piston and out through its open bottom into the heating system. As soon as the pressure on the under side is as great as that for which the weight is set the piston rises and live steam is shut off.

Another variety consists of a balanced valve having two discs of the same size on the same stem. The live steam presses up against one disc and down against the other. As these discs are of the same size the live steam has no tendency to move the valve. Motion is produced by a weight and lever which tend to open the valve, and by the action of the low pressure steam on a diaphragm, which tends to close it. An adjustable spring is sometimes used in place of a weight and lever.

Q. With a reducing valve, how can the pressure in the heating system be raised or lowered?

A. By moving the weight on the lever or adjusting the tension on the spring.

Q. What fittings should be placed on the main supply pipe of a reducing system?

A. A stop or throttle valve, a reducing valve and a low reading pressure gauge.

Q. What openings has the receiver tank?

A. One for the entrance of condensed steam from the heating system ; one for the entrance of city water ; one for emptying the tank ; one for a vent to the atmosphere ; finally, one connecting with the suction of the boiler feed pump.

Q. What fittings are often placed on a receiver tank?

A. A water gauge glass, to show the level at which the water stands in the tank, and a device consisting of a float and lever which opens the valve admitting steam to the pump whenever the level of the water in the tank rises above a certain height.

Q. To which system does the ordinary method of heating with exhaust steam belong?

A. To the reducing system. The steam engine takes the place of the reducing valve.

Q. Why is it necessary to employ an oil separator when exhaust steam is used for heating?

A. In order to extract the oil which has been taken up by the steam in its passage through the cylinder.

Q. What harm would result in leaving the oil in the exhaust steam?

A. This oil would accumulate in the pipes and boiler. It would leak out of joints in the piping and at the seams and tube ends of the boiler. It would also produce foaming.

Q. What is the Webster vacuum system?

A. It is a reducing system in which the circulation is produced by a vacuum pump attached to the return pipes.

Q. What are the advantages of the Webster vacuum system?

A. It diminishes the back pressure on the engine, and allows the use of a smaller size of pipes; different radiators on the same system may be kept at different temperatures, and radiators may be operated at a level below that of the receiving tank.

Q. Describe that method of piping known as the single pipe system.

A. Each radiator has but one outlet and one valve. The condensed steam flows back through the same branch pipes and risers as carry the steam supply, and is collected in a trap, from which it is taken to the boiler in the same way as in the double pipe system.

Q. What are the advantages and disadvantages of the single pipe system?

A. Its chief advantage is its lower first cost. It has the disadvantage of a poorer circulation.

QUESTIONS FOR MARINE ENGINEERS.

Engineers desiring to enter the Merchant Marine are required to pass an examination before the Supervising Steam Inspector of their district. The name and address of the Inspector can be obtained from the Secretary of the Treasury.

The requirements for engineers are not very definitely established by law, as will be seen by reading the extract from the rules of the Board of Supervising Inspectors. (See p. 132.)

In a bill introduced by Senator Wm. P. Frye, which embodies the recommendations of the United States Delegates to the International Marine Conference, the requirements of the various grades are presented in much greater detail. Although this bill was not passed, the recommendations therein contained have had an undoubted influence, and act as a guide to the supervising steam inspectors in determining upon the fitness of applicants.

In the following extracts from the Rules and Bill will be found only those sections that apply particularly to the qualifications of marine engineers and to the range of subjects in which they must be proficient.

As the requirements for chief engineer extend beyond the scope of the "Roper's Handy-Books," no questions for that grade have been included in this book.

EXTRACT FROM THE RULES AND REGULATIONS OF THE BOARD OF SUPERVISING INSPECTORS OF STEAM VESSELS.

1. Before an original license is issued to any person to act as a master, mate, pilot, or engineer, he must personally appear before some local board or a supervising inspector for examination; but upon the renewal of such license, when the distance from any local board or supervising inspector is such as to put the person holding the same to great inconvenience and expense to appear in person, he may, upon taking the oath of office before any person authorized to administer oaths, and forwarding the same together with the license to be renewed, to the local board or supervising inspector of the district in which he resides or is employed, have the same renewed by the said inspectors if no valid reason to the contrary be known to them; and they shall attach such oath to the stub end of the license, which is to be retained on file in their office; *Provided, however,* That the applicant for renewal is at the time personally within the jurisdiction of the United States Inspection Laws, as defined in sections 4400 and 4447 of the Revised Statutes.* And inspectors are directed when licenses are completed, to draw

* Proviso substantially repealed by Act of Congress approved May 28, 1896.

a broad pen and red-ink mark through all unused spaces in the body thereof, so as to prevent as far as possible illegal interpolation after issue.

Mates, assistant engineers, or second-class pilots serving under five-years' license, entitled by license to raise of grade, shall have issued to them new licenses for the grade for which they are qualified, the local inspectors to forward to the supervising Inspector-General the old license when surrendered, with the report of the circumstances of the case. New licenses may also be issued in the case of license lost by wreck, fire, or any other cause, upon a satisfactory showing of such loss to the inspectors, duly sworn to.

And inspectors will, before granting an original license to any person to act as an officer of steam vessels, require the applicant to make his written application upon the blank form authorized by the Board of Supervising Inspectors, which application shall be filed in the records of the inspector's office. Inspectors shall also, when practicable, require applicants for pilot's license to have written indorsement of the master and engineer of one vessel upon which he has served, and of the licensed pilot as to his qualifications. In the case of applicants for original engineer's license, they shall also, when practicable, have the indorsement of the master and engineer of a vessel on which they have served, together with one other licensed engineer.

No original master's, mate's, pilot's, or engineer's license shall be issued hereafter or grade increased except upon written examination, which written examination shall be placed on file as records of office of the inspectors issuing said license.

Any applicant for examination for license who has been refused for want of knowledge or other qualifications, may come before any local board for re-examination after one year has expired, on presentation of a letter from the board that had refused him.

Any person who has served as master, commander, pilot, or engineer of any steam vessel of the United States, in any service in which a license as master, commander, pilot, or engineer was not required at the time of such service, shall be entitled to license as master, commander, pilot, or engineer, if the inspectors, upon written examination as required for applicants for original license, may find him qualified; *Provided*, That the experience of any such applicant within three years of making application has been such as to qualify him to serve in the capacity for which he makes application to be licensed; but no such license shall be granted except under such restrictions as may be prescribed by the supervising inspector of the district in which the applicant files his application. (Officers of the naval militia who are) applicants for license as master or pilot of steam vessels of the naval militia, after passing an examination for color blindness, may be examined by the inspectors as to their knowledge of the pilot rules and handling of vessels, and if the applicant be found qualified in the judgment of the inspectors, he may be granted a special license as master or pilot on such vessels on the waters of the district in which such license is granted, and for no other purpose.

All licenses issued to officers of the naval militia provided for in the preceding paragraph of this section, or in section 3 of this rule, shall be surrendered upon the party holding it becoming disconnected from the naval militia by resignation or dismissal from such service ; and no license shall be issued as above except upon the official recommendation of the chief officer in command of the naval station of the State in which the applicant is serving.

2. The classification of engineers shall be as follows :

CHIEF.

Chief engineer of ocean steamers.

Chief engineer of condensing lake, bay, and sound steamers.

Chief engineer of non-condensing lake, bay, and sound steamers.

Chief engineer of condensing river steamers.

Chief engineer of non-condensing river steamers.

Any person holding chief engineer's license shall be permitted to act as first assistant on any steamers of double the tonnage of same class named in said chief's license.

Engineers of all classifications may be allowed to pursue their profession upon all waters of the United States, in the class for which they are licensed, if found upon examination qualified therefor.

FIRST ASSISTANT.

First assistant engineer of ocean steamers.

First assistant engineer of condensing lake, bay, and sound steamers.

First assistant engineer of non-condensing lake, bay, and sound steamers.

First assistant engineer of condensing river steamers.

First assistant engineer of non-condensing river steamers.

Engineers of lake, bay, and sound steamers who have actually performed the duties of engineers for a period of three years shall be entitled to examination for engineer of ocean steamers, applicant to be examined in the use of salt-water method employed in regulating the density of the water in boilers, the application of the hydrometer in determining the density of sea water, and the principle of constructing the instrument, and shall be granted such grade as the inspectors may find him competent to fill.

Any assistant engineer of ocean steamers of 1500 gross tons burden and over, having had actual service in that position for one year, may, if the local inspectors in their judgment deem it advisable, have his license indorsed to act as chief engineer on lake, bay, sound, or river steamers of 750 gross tons or under.

SECOND ASSISTANT.

Second assistant engineer of ocean steamers.

Second assistant engineer of condensing lake, bay, and sound steamers.

Second assistant engineer of non-condensing lake, bay, and sound steamers.

Second assistant engineer of condensing river steamers.

THIRD ASSISTANT.

Third assistant engineer of ocean steamers.

Third assistant engineer of condensing lake and sound steamers.

First, second, and third assistant engineers may act as such on any steamer of the grade of which they hold license or as such assistant engineer on any steamer of a lower grade than those to which they hold a license.

Inspectors must designate upon the certificate of any chief or assistant engineer the tonnage of the vessel on which he may act ;

Provided, however, That any engineer whose license is designated by tonnage may act in similar capacity on any steamer of larger tonnage, provided the engine in said steamer is not larger than the one to which his tonnage license restricted him. That Form 2130½, special license to engineers, be issued only to engineers in charge of vessels of 10 tons and under, and that all other licenses to engineers be issued on Forms 2129 and 2130, according to grades specified in this section.

3. Assistant engineers may act as chief engineers on high-pressure steamers of 100 tons burden and under of the class and tonnage or particular steamer for which the inspectors, after a thorough examination, may find them qualified.

In all cases where an assistant engineer is permitted to act as first (chief) engineer, the inspectors shall state on the face of his certificate of license the class and tonnage of steamers or the particular steamer on which he may so act.

Any (officer of the naval militia who is an) applicant for license as chief engineer or assistant engineer of steam vessels of the naval militia may be examined by inspectors and granted a special license as such, and for no other purpose, if, in the judgment of the inspectors, he is qualified. (See last paragraph of Section 1 of this rule.)

4. It shall be the duty of an engineer, when he assumes charge of the boilers and machinery of a steamer to forthwith thoroughly examine the same, and if he finds any part thereof in bad condition, caused by neglect or inattention on the part of his predecessor, he shall immediately report the facts to the local inspectors of the district, who shall thereupon investigate the matter; and if the former engineer has been culpably derelict of duty, they shall suspend or revoke his license.

5. No person shall receive an original license as engineer or assistant engineer, except for special license on small pleasure steamers of 10 tons and under, and ferryboats, saw-mill boats, pile-drivers, and other nondescript similar small vessels, navigated outside of ports of entry and delivery, who has not served at least three years in the engineer's department of a steam vessel, a portion of which experience must have been obtained within three years preceding the application;

Provided, That any person who has served a regular apprenticeship to the machinist trade in a marine-engine works for a period of not less than three years, and any person who has served for a period of not less than three years as a locomotive engineer, stationary engineer, or as an apprentice to the machinist trade in a locomotive or stationary-engine works, and any person who has graduated as a mechanical engineer from a duly recognized school of technology, may be licensed to serve as an engineer on steam vessels, after having had not less than one year's experience in the engine department of steam vessels, which experience must have been obtained either within one year before or one year subsequent to the acquisition of the skilled knowledge above mentioned (which fact must be verified by the certificate in writing of the licensed engineer or master under whom the applicant has served, said certificate to be filed with the application of the candidate) ; and no person shall receive license as above, except for special license, who is not able to determine the weight necessary to be placed on the lever of a safety valve (the diameter of valve, length of lever, distance from center of valve to fulcrum, weight of lever, and weight of valve and stem being known) to withstand any given pressure of steam in a boiler, or who is not able to figure and determine the strain brought on the braces of a boiler with a given pressure of steam, the position and distance apart of braces being known, such knowledge to be determined by an examination in writing and the report of examination filed with the application in the office of the local inspectors; and no engineer or assistant engineer now holding a license shall have the grade of the same raised without possessing the above qualifications. And no original license shall be granted any engineer or assistant engineer who cannot read and write and does not understand the plain rules of arithmetic.

EXTRACTS FROM THE FRYE BILL.

SECTION 128. That no steam vessel can obtain a clearance or legally proceed to sea from any port in the United States or navigate any waters of the United States which are common highways of commerce or open to competitive navigation, excepting public vessels of the United States and vessels of other countries, unless the engineers thereof have obtained and possess valid certificates of competency or certificates of service appropriate to their several stations.

SEC. 129. That the minimum complement of engineers for vessels licensed for carrying passengers shall be as follows:—Seagoing steamers: Twin-screw steamers with machinery of over ten thousand indicated horse-power, one chief engineer of the highest grade and nine assistant engineers, of whom at least three shall hold certificates as first assistants and three as second assistants.

SEC. 130. Twin-screw steamers with machinery from five thousand to ten thousand indicated horse-power, one chief engineer of the grade from five thousand to ten thousand indicated horse-power and nine assistants, of whom at least three shall hold certificates as first assistants and three as second assistants.

Sec. 131. Single-screw steamers with machinery of over ten thousand indicated horse-power, one chief engineer of the highest grade and six assistants, of whom at least three shall hold certificates as first assistants and two as second assistants.

Sec. 132. Single-screw steamers with machinery of from five thousand to ten thousand indicated horse-power, one chief engineer of the grade from five thousand to ten thousand indicated horse-power and five assistants, of whom at least three shall hold certificates as first assistant and one as second assistant.

Sec. 133. Single-screw steamers with machinery of from two thousand to five thousand indicated horse-power, one chief engineer of the grade and five assistants, if there are many auxiliaries independent of the main engines; if there are very few auxiliaries, three assistants. In the first case, at least three of the assistants shall hold certificates as first assistant and one as second assistant; in the second case, two shall be first assistants and one second assistant.

Sec. 134. Single-screw steamers with machinery of less than two thousand indicated horse-power, one chief engineer of the grade, except as provided for the cases where first and second assistants may be in charge, and two assistants, of whom one shall be a first assistant.

Sec. 135. Paddle-wheel steamers, one chief engineer of grade according to horse-power and two to five assistants, depending on number of auxiliaries. If there are five assistants three shall hold certificates as first assistant and one as second assistant; if there are less than five assistants, at least one shall hold a certificate as first and one as second assistant.

Sec. 136. Steamers navigating lakes, bays, sounds, and rivers: There shall in every case be a chief engineer of the grade corresponding to the horse-power, except, as elsewhere provided, when first and second assistants are allowed in charge, and a number of assistants depending on the size and complexity of the machinery and the duration of the trip between terminals; but in no case shall any steamer on routes of longer than fourteen hours' duration be allowed to run with less than two engineers, including the chief engineer, and when there is only one assistant he shall hold a certificate at least as high as second assistant, provided that in the case of small pleasure steamers of ten tons and under a third assistant engineer may have charge of the machinery.

Sec. 137. That on every steamer engineers holding a certificate of higher grade than that required may perform the duties of the lower grade.

Sec. 138. That before a steamer is licensed for carrying passengers the supervising inspector of the district must be notified of the service she is intended to perform, and he shall make personal inspection of the machinery and decide upon the minimum complement of engineers in those cases where it is not specifically provided for. In his decision he will be governed by the arrangement and complexity of the machinery, the subdivision of water-tight bulkheads, and all other matters which increase the difficulty of properly caring for the machinery.

Sec. 139. That in all cases, including those specifically provided for, he is authorized to increase the complement if, in his judgment, the complexity and arrangement of the machinery, the number of auxiliaries, and the arrangement of bulkheads make it necessary to the adequate care and supervision of the machinery while in operation. Should the owner of the steamer deem the number assigned too great he may appeal to the Supervising Inspector-General, transmitting plans of the vessel and machinery in sufficient detail to enable an intelligent decision to be rendered.

Sec. 140. That, in the case of steamers used entirely as freight-carriers and not carrying passengers, the number of engineers shall be decided by the supervising inspector after a personal inspection and knowledge of the intended service.

Sec. 141. That in all cases there shall be a chief engineer of the appropriate grade, except as elsewhere provided, when first and second assistants are allowed in charge.

Sec. 142. That, if the vessel is a seagoing one and the duration of the voyage is more than forty-eight hours, there shall always be at least three engineers, including the chief, and one of the assistants must hold a certificate as first assistant. If the voyage lasts less than forty-eight hours there may be two engineers only.

Sec. 143. That if the vessel does not go to sea, but navigates only bays, sounds, lakes, and rivers, there must be two engineers if the average number of hours under way per day exceeds ten or if the number of hours for any single regular run exceeds twelve. Where the duration of the trip is less than herein specified one engineer only will be required.

Sec. 144. That in the case of pile-drivers, saw-mill boats, and other small craft, not carrying passengers, a third assistant engineer may have charge of the machinery if it does not exceed one hundred indicated horse-power. That a special certificate may be granted authorizing the holder to act as engineer on steamers of ten tons and under, not carrying passengers or freight for pay, if the local inspectors are satisfied that the candidate is competent.

Sec. 145. That the classification of engineers in the merchant service of the United States shall be as follows: Chief engineer of machinery exceeding ten thousand indicated horse-power, chief engineer of machinery between five thousand and ten thousand indicated horse-power, chief engineer of machinery between two thousand and five thousand indicated horse-power, chief engineer of machinery of two thousand indicated horse-power and less, first assistant engineer, second assistant engineer, third assistant engineer.

Sec. 146. That first assistant engineers may act as chief engineers of engines of less than three hundred indicated horse-power and second assistant engineers may have charge of engines of less than one hundred indicated horse-power, provided the vessel in which such engines are placed is used in river or harbor service only or does not go to sea beyond twenty miles.

Sec. 147. That a chief engineer for engines of ten thousand indicated horse-power and upward must be at least thirty years old and must have served at least five years at sea as a chief engineer or first assistant with engines of over two thousand indicated horse-power. He must be able to superintend the construction of machinery for two thousand indicated horse-power and upward, and to devise and direct the repair of any accident to the machinery likely to occur. He must be able to secure a general average of ninety per centum on the examination for chief engineer hereinafter provided for and an average of seventy-five per centum on such additional questions as may be given by the examining board for this grade and the next lower.

Sec. 148. That the requirements for a chief engineer for machinery of from five thousand to ten thousand indicated horse-power shall be the same as for a chief engineer for machinery of over ten thousand indicated horse-power, except that he shall only be required to secure an average of eighty per centum on the general examination for chief engineer and seventy per centum on the special questions for this grade and the next higher.

Sec. 149. That a chief engineer for machinery of from two thousand to five thousand indicated horse-power must be at least thirty years of age and have served at least five years as chief engineer of a seagoing steamer or as first assistant with engines from two thousand to five thousand indicated horse-power. He must be able himself to do or direct the adjustment of any part of the engines and to run the lines for them and erect them in the vessel. He must be conversant with work on boilers and piping and able to direct the repair of any accident to them as well as the accidents likely to occur to the engines. He must secure seventy-five per centum on the general examination for chief engineer.

SEC. 150. That a chief engineer for machinery of two thousand indicated horse-power or less must be at least thirty years of age and must have served at least five years as a first assistant or three years as a first assistant with engines of two thousand indicated horse-power and over in a sea-going ship. He must be able to make himself or to direct the making of any ordinary repairs to any part of the machinery. He must secure sixty-five per centum on the general examination for chief engineer.

SEC. 151. That a first assistant engineer must be at least twenty-five years of age and must have served at least two years as a second assistant. He must understand the working of every part of the machinery and be able himself to make the adjustment directed by the chief engineer. He must understand the use of all the mechanics' tools employed in work about marine machinery and be himself skilled at some trade connected with the making or fitting of such machinery. He must secure at least sixty-five per centum on the examination for his grade.

SEC. 152. That a second assistant engineer must be at least twenty-three years of age and must have served at least one year as a third assistant. He must understand the working of marine machinery and be able to start, stop, and care for it while in motion. He must understand the usual remedies for such things as heated journals, low water, and foaming, and be able to fit and adjust bearings, pack stuffing boxes, and do other ordinary work about marine machinery. He must be proficient in some trade connected with the building of marine machinery. He must secure at least sixty-five per centum on the examination for his grade.

SEC. 153. That a third assistant engineer must be at least twenty-one years of age. He must either be a machinist by trade and have had at least one year's experience with engines and boilers on a vessel or on shore, or be a journeyman mechanic in a trade connected with the building of marine machinery, and have had one year's experience in the engine department of a steam vessel or two years' experience with engine and boiler on shore, or have had at least three years' experience in the engine department of a steam vessel. He must secure at least sixty-five per centum at the examination for his grade.

SEC. 154. That the examinations for the two higher grades of chief engineer shall be held by a board consisting of the supervising inspector of the district and two local inspectors of boilers, and shall take place not oftener than twice a year, and only then if there are applicants. The examination for the other two grades of chief engineer shall be held by a board of three local inspectors of boilers. These shall be held at least twice a year, and once a quarter if there are more than five applicants.

SEC. 155. The examination for first, second, and third assistant engineers shall be conducted by the local inspector of boilers at least once each quarter if there are applicants.

SEC. 156. That when an applicant for any of the grades of engineers hereinbefore enumerated has not had the service in the merchant marine of the United States contemplated, but has had equivalent service with marine machinery elsewhere, of which he can produce satisfactory evidence, he shall be admitted to examination, and, if found to be possessed of the requisite degree of proficiency, shall be certificated the same as if his previous service had been in the merchant marine of the United States.

SEC. 157. That applicants for every grade of engineer must satisfy the examining board that they are of sober and correct habits; and, if called upon by the examining board to do so, must furnish the names of the vessels on which they have previously served, together with the names of the masters and chief engineers, to whom the board may address interrogatories if they deem it necessary to establish the character of the applicant. If the service has been on shore the testimonials must be signed by an employer.

SEC. 158. That nothing contained in the foregoing rules is to be construed to deprive any engineer of the certificate which he now holds or of the privilege of renewal in accordance with the rules heretofore existing, except as hereinafter provided.

Sec. 159. That, if an engineer with a certificate desires to qualify for duty with machinery of greater horse-power than that of the class with which he is serving, he must make application and pass the examination provided for above for such higher class of machinery, and this is to apply to the various grades of assistants as well as to those of chief; that is, an engineer may continue to hold his certificate for the same kind and power of machinery, but if he desires to serve with larger or different machinery he must pass the examination for the grade he desires to hold, as herein provided.

Sec. 160. That solutions of problems and answers to questions shall be given in ink, and no candidate will be permitted to leave the examiner's room until a paper is finished and handed in, and all the examination papers shall be referred to the Supervising Inspector-General of Vessels, with the examiner's recommendations indorsed thereon and placed on file. Any examiner, officer, or employee of the inspection service assisting a candidate in any manner in the solution of his questions will be dismissed from the service.

Sec. 161. That, in case it shall be proved by oath or affirmation that the certificate of competency or the certificate of service of a master, mate, or engineer has been lost, destroyed, or unintentionally mislaid, the same shall be reissued from the records in the office of the Supervising Inspector-General of Vessels, through the inspector to whom the application for renewal is made.

Sec. 162. That all certificates of competency and of service shall be made in duplicate, one copy of which, under the seal of the Treasury Department and hand of the Supervising Inspector-General of Vessels, shall be issued to the person entitled to the same by the inspector before whom the candidate appeared for examination, by which inspector the certificate shall be sealed and countersigned.

Sec. 163. That the qualifications required for the several grades below mentioned shall be as follows: — Third assistant engineer: *First.* He must know the names of the different parts of a steam engine and boiler and of the fittings and mountings, including condenser and pumps.

Second. He must be able to lay and start fires and raise steam and understand the precautions to be taken to prevent injury to the boiler; must know how to "tend water," fire, and clean fires; also what to do in case of low water.

Third. He must be able to start, stop, and reverse the engine, and know what precautions to observe in starting to prevent injury to engines and boilers.

Fourth. He must know what to do to engines and boilers in case of foaming, and the course to be pursued in the case of hot bearings.

Fifth. He must be able to read the steam and vacuum gauges and other instruments about the machinery intelligently.

Sixth. He must know the first four rules of arithmetic and be able to write a legible hand.

Sec. 164. Second assistant engineer : *First.* He must be able to give a description of the boilers and engines in common use on board ship and of the fittings and connections used with them, including the way in which boilers are braced, and the use and management of the different valves, cocks, levers, and so forth.

Second. He must be able to tell how ordinary repairs to boilers are made, such as hard and soft patching, riveting, expanding tubes, calking seams, plugging leaky tubes, and so forth.

Third. He must understand the use of the thermometer, barometer, salinometer, steam and vacuum gauges, gauge cocks, and glass water gauges, and in general all other fittings about the machinery.

Fourth. He must be able to tell what foaming and priming are, how discovered, and their effects on boilers and engines, and what is done to stop them.

Fifth. He must be able to tell the course to be pursued in raising steam and getting engines and boilers ready for work, and the process followed when the machinery is no longer needed on reaching port, including both the cases when the fires are to be banked and when the boilers will not be needed for several days.

Sixth. He must be able to tell how to ascertain whether the journals are working properly and what to do to prevent heating, and to remedy it if it does occur.

Seventh. He must be able to tell how firing should be conducted and how a fire should be cleaned.

Eighth. He must be able to tell what to do in case of low water.

Ninth. He must be able to tell how to lay up packing and how to pack stuffing boxes, pump pistons, and so forth.

Tenth. He must know enough arithmetic to be able to work any problem under the fundamental rules and common fractions. He must be able to write a legible hand and write an ordinary letter so as to show a fair knowledge of spelling and grammar.

SEC. 165. First assistant engineer: *First.* Familiarity with all the ordinary types of engines and boilers; explanation of the different parts, their object, and method of working.

Second. Duties in raising steam and getting under way; in maintaining a good performance while under way; and when ship is anchored or secured.

Third. Description of common derangements that may happen, such as foaming, hot journals, and so forth, with account of procedure to remedy them; also tell what should be done to prevent them.

Fourth. Repairs: Tell how patches are put on a boiler, tubes expanded, and so forth.

Fifth. Adjustment of journals and valve gear; setting of valves.

Sixth. Use of steam-engine indicator and explanation of diagrams taken with it, as well as calculation of indicated horse-power from diagram.

Seventh. Expansion of steam; object of; how accomplished in practice.

Eighth. Familiarity with instruments used about machinery, steam and vacuum gauges, thermometer, barometer, and so forth; how they should be fitted to insure accurate readings.

Ninth. Fittings and mountings of engines, boilers, and auxiliaries; description of safety valves, safety-feed arrangements, gauge cocks, and glass gauges on boilers, and so forth.

Tenth. Description of the steam pumps in common use, and explanation of any derangements to which they are liable.

Eleventh. Problems in connection with measurement of coal bunkers, oil tanks, position of weight on safety-valve lever, and so forth.

Twelfth. Acquaintance with the rules of arithmetic through percentage and proportion, and of mensuration, to enable the solution of such problems as in paragraph eleven. Legible handwriting and knowledge of spelling and grammar.

Thirteenth. Ability to make a sketch, with figured dimensions, from the machinery, so that in case of a broken part a new one could be made from his sketch.

SEC. 166. Chief Engineer.—*First.* Boilers: These shall include all the common makes of boilers likely to be found in any vessel on which the applicant would serve, and also a knowledge of how the various parts are put together, the advantages of different kinds of riveting, the methods of bracing, the attachments commonly used, including improved forms, and the use of forced draft, and the changes in boilers consequent thereon.

Second. Engines: The different kinds in common use, including those used with paddle wheels; description of their different parts and methods of fitting them together.

Third. Valves: Different kinds in common use and advantages of forms now in use over older ones which have been abandoned. How to set valves. Cut-off, how effected, and how different points of cut-off change dimensions of valve. Descriptions of modern valve gears with screw and paddle engines, explanation of working, and how variable cut-off is secured with them. Derangements common to valves and valve gears.

Fourth. Journals: How fitted in different places, provision for lubrication for preventing heating, and for taking up wear. This is to include shaft and connecting rod journals and thrust bearings.

Fifth. Condensers: Object of, explanation of forms in common use. Methods of packing tubes, preventing crawling, and for good distribution of the steam.

Sixth. Pumps: Air, circulating, feed, and auxiliary pumps: Description of the varieties in common use. Description of their connections, as of air and circulating pumps to the condenser. Vacuum, how produced; value of and how affected by derangement of pumps or peculiarities of working of engine.

Seventh. Propelling instruments, including screw and paddle wheel: Description of the forms in common use and explanation of the advantages of forms now in use over older ones. Description of methods of securing propelling instruments to shafts and of bearings for same.

Eighth. Electric machinery: Practical description of dynamo-electric machines as fitted on board ship and of the parts requiring adjustment. Accidents likely to occur to dynamos, and what to do to remedy them. Practical points on the wiring of ships, and points to be looked after to insure good working. Electric lamps and connection to mains.

Ninth. Refrigerating and hydraulic machinery: Description of the forms commonly fitted on board ship. Description of process of working and statement of points to be looked after to insure good working.

Tenth. Care of machinery: This will include questions in regard to precautions to be observed in raising steam so as to prevent injury to engines and boilers; precautions to be observed to prevent derangements while in operation; procedure on reaching port and laying up for a few days; and procedure when engines and boilers are to be laid up for a long period, say of several months or more.

Eleventh. Accidents liable to occur, even with care, and how to remedy them.

Twelfth. Accidents liable to occur due to carelessness or neglect, and what should be done if they do occur.

Thirteenth. Accidents that have occurred in applicant's own experience, or of which he knows, and what was done to remedy them.

Fourteenth. List of machine and hand tools usually carried on board ship, and general idea of work that can be done on board in any case of necessity.

Fifteenth. Economy in the use of stores. Tell how engines should be run, firing of furnaces conducted, and lubrication looked after and regulated so as to secure the best economy. Effect of change of pitch of propeller on economy. Also of variation in ratio of heating to grate surface.

Sixteenth. He must be acquainted with the principles of expansion and the modern theory of heat, and be able to solve, with the assistance of his own books or without books, according as the examination papers may be set, questions in economy and duty in connection with engines and boilers.

Seventeenth. He must understand how to apply the indicator and to draw the proper conclusion from diagrams, and to construct the approximate diagrams for any given data.

Eighteenth. He must be able to produce, without a copy, a fair working drawing of any of the machinery, with figured dimensions fit to work from.

Nineteenth. Strength of materials: Calculations for thickness of boiler shells, size of bolts to stand a given strain, and so forth.

Twentieth. Inspection of coal, oil, and so forth. Points to be desired and those to be avoided.

Twenty-first. He must be able to explain the formation of scale and the precipitation of salt, and the precautionary means adopted in respect thereto, with jet condenser and with surface condenser.

Twenty-second. He must understand the general principles involved in the construction of the vacuum and steam gauges, of the barometer, thermometer, and salinometer.

Twenty-third. He must be familiar with the general results obtained from past experience in relation to corrosion, pitting, and galvanic action in boilers, and the use of zinc and of soda in boilers.

Twenty-fourth. He must possess an intelligent knowledge of the properties of the lubricants, boiler cements, and india rubber in general use in steamers.

Twenty-fifth. He must understand the cause of spontaneous combustion and the formation of explosive gases in coal holes and the precautionary measures proper to prevent accidents from these causes.

Sec. 167. Special examination for the two highest grades of chief engineer: *First.* Theory of the steam engine. Explanation of the advantages of multiple expansion engines, steam jacketing, high speeds, and so forth.

Second. Theory of boiler design and construction. Effect of changes in ratios of heating and grate surface area through tubes and chimney. Production of draft, natural and forced. Influence of proportions on economy of steam production. Features of design requiring special care to insure good circulation, prevent foaming, and so forth.

Third. Theory of boiler incrustation and corrosion and explanation of means taken to prevent and remedy effects of same.

Fourth. Theory of condensers and connected pumps. Elements necessary to economy and efficiency.

Fifth. Design of machinery and boilers of a given power.

Sixth. Strength of materials. Ability to calculate necessary size of any part of the machinery and boilers.

Seventh. Theory of friction as presented in marine machinery: Anti-friction metals. Lubrication and lubricants, including inspection and tests of latter.

Eighth. Valves and valve gears. Thorough knowledge of the various kinds, the theory of their action, advantages and disadvantages, and what considerations govern the choice of a particular valve gear for special use.

Ninth. Theory of electric light installations on board ship, including details of dynamos, wiring, safety fuses, and so forth; care of dynamos; precautions to be followed in wiring and so forth.

Tenth. Theory of refrigerating machinery and precautions to be looked after in its installation.

Eleventh. Theory of hydraulic machinery, including pumps, hoists, steering gear, and so forth; details of installation and so forth.

Twelfth. Building machinery and erection of same on board ship. The applicant must be able to tell the whole process of building any part of the machinery and boilers, and give the details of its alignment and erection on board ship.

Thirteenth. Questions on supposititious break-downs will be given, and the applicant asked for his explanation of the best method of repair, if a repair is practicable, or what should be done to get the vessel into port if the break cannot be repaired.

Fourteenth. Questions will be given to test the ability of applicant to estimate the time and cost for repairs to be made in port, full details of the parts to be repaired being given.

QUESTIONS FOR THIRD ASSISTANT ENGINEERS.

Q. What is a damper, and where is it placed?

A. A damper is an apparatus for controlling the supply of air to boiler furnaces. They are fitted sometimes in the funnel and sometimes at the mouth of the ashpit. They are to be closed whenever the engines are stopped; when there is priming in the boiler, or in any case where it is desired to diminish combustion.

Q. When there are no dampers, what is done instead of closing the damper, and what is the objection to this?

A. The doors of the smoke boxes and the furnaces are opened. This is very objectionable, because the sudden rush of cold air striking the heated surface of the boiler produces contractions which are liable to result in cracked tubes or plates and in leaks.

Q. What are the necessary fittings of a marine boiler?

A. A funnel with its air casings, the up-takes, smoke-boxes, and doors, fire doors, bars, bridges; main stop-valves, safety valves, and thier drain pipes; feed check valves; blow-off and scum cocks; water gauge glasses, water gauge cocks, and steam whistle.

Q. Through what apparatus does the steam pass from the time it leaves the boiler until it returns again?

A. The boiler, steam pipes, cylinder, condenser, air-pump, hot well and feed pump.

Q. How many blow-off cocks are there and why?

A. One on the bottom of the boiler and one on the ship's side. When both are open water will run from the sea into the boiler if steam is not up; if steam is up its pressure will blow the water out. The object of having two cocks is to provide against one of them being open.

Q. Suppose that the upper cock of the water gauge should be closed or choked up, where would the water stand?

A. At the top of the glass.

Q. And if the upper one were opened with the lower one closed?

A. The water would remain at the same level that it had.

Q. In testing the height of the water by the gauge cocks, which one would you open first and what should come out?

A. The bottom one. Water.

Q. Which one would you open next?

A. The top one, and I should expect steam to come out.

Q. Suppose that water comes out of the top one also, what would you do?

A. I would blow off until water was at the proper level.

Q. Suppose that steam had come out the bottom one, what would you have done?

A. I would check the fires instantly, closing the dampers, then I would draw them. I would shut down the engine, and as soon as the boiler had cooled off would pump in water. I would examine both ends of the boiler to see if the tubes are leaking, and if they are, I would attempt to stop them by expanding the ends; if this did not remedy the leaking of all, I would plug up the worst ones.

Q. How would you change the water in the boiler when the steam is up?

A. By increasing the feed and opening the scum cock.

Q. Suppose that the scum cock is stuck fast, what would you do?

A. I would open the blow-off cocks.

Q. Suppose that upon attempting to relieve the pressure on the boilers through the safety valve you found that it was stuck, what would you do?

A. I would check the fires and draw them, and as soon as the boiler was sufficiently cool would repair the valve.

Q. What might be the effect of letting the water in the boiler get too low?

A. The top of the combustion chamber and the tubes might be burned, or it might even cause an explosion.

Q. What might be the effect of too high water in the boiler?

A. Priming, and possibly the breaking of the cylinder head.

Q. Explain how you would proceed in starting a new fire in the boilers.

A. I would first see that the valves in the water gauge were open and would try the gauge cocks. Having found that the water level was all right I would cover the grate bars with a thin layer of coal; then, if I had fire in another boiler, I would take two or three shovelfuls from this other boiler and put it on the grate and throw on either soft coal and wood or shavings and then gradually add fresh coal. I would open the upper gauge cock in the boiler so as to let the air that is contained in the water escape.

Q. How would you clean your fires?

A. I would let the fire burn down on one side from front to back, meanwhile keeping the other side in good condition; then I would pull out the ashes and clinkers from the side that had burned down, cleaning all the walls at the same time, and would pull over the good part of the fire from the other side and put on fuel as fast as it was needed; then, after allowing the clinkers and ashes to cool, I would pull them out, and proceed in the same way as on the first side.

Q. What regulates the depth of fuel to be carried on the grates?

A. The draft.

Q. What is priming, and what causes it?

A. Priming is the carrying over of water from the boiler into the engine in the form of a spray. It may be caused by poor design of the boiler giving too small a steam space; or, in a well-designed boiler, it may be caused by carrying the water at too high a level and by irregular firing.

Q. How can you tell whether there is priming or not?

A. Priming often causes a clicking sound in the cylinder of the engine. By opening a valve and allowing steam to escape into the air the appearance of the jet will tell whether the steam is dry or not. If it has a milky or cloudy appearance close to the orifice there is evidently priming.

Q. What would you do in case you found there was priming?

A. I would open the cylinder drip cocks and close the damper of the boiler and lower the water level.

Q. What sometimes causes the appearance of flame at the top of a funnel, and is this desirable or not?

A. Whenever flames come out of the top of a funnel this shows that the gases have not been united within the combustion chamber as they should have been. The cause of this would be a too small supply of air in the combustion chamber. Combustion taking place outside of a boiler is extremely undesirable, as it means a waste of fuel.

Q. How can you prevent salting of the boiler?

A. By scumming and blowing off a part of the water in the boiler.

Q. How can you tell the density of the water in the boiler?

A. By the reading of the salinometer.

Q. What density is proper?

A. A density such that the salinometer reads about $\frac{2}{32}$.

Q. How is the salinometer made, and how do you use it?

A. The salinometer consists of a glass bulb carrying a weight on its bottom and a graduated stem attached to its top, the graduations being in 32ds or 33ds. To use it, all that is necessary is to put it in a vessel of the fluid whose density it is desired to know, and it will sink to the amount corresponding to the density. The reading of the stem, which is just even with the surface of the liquid, will tell what the density is.

Q. What are scum cocks?

A. They are cocks placed on a boiler for the purpose of getting rid of any dirt which may be floating on the surface of the water in the boiler; they are placed, therefore, a little below the usual water line. They are connected by a pipe which leads to another cock on the vessel's side.

Q. When you receive an order to stop the engines, what would you shut and what would you open?

A. I would shut the throttle valve and the sea injection valve and would also close the dampers. I would open the safety valve.

Q. What would you do before starting an engine?

A. I would warm it up by opening the drain cocks and blowing steam through it and the condenser. I would also examine the various valves, including the injection and discharge valves, to see that they are open or free to open, as the case may be.

Q. Explain in detail what valves and cocks should be opened before starting the engine.

A. The main stop valve, the check valve, the drain cocks on cylinders and jackets, the blow-through cocks, the sea inlet for circulating water.

Q. What would you do in case the engine were racing?

A. I would attach the governor, if there were one, and I would stand at the throttle valve ready to close it as the steam rises. I should also run with a lowered boiler pressure and would ease up on the injector.

Q. Why is soda sometimes put into a boiler, and what kind of soda is used?

A. Common washing soda is put in boilers in order to neutralize any acid that may be in the feed-water which might cause pitting.

Q. How can you prevent the formation of black smoke?

A. Black smoke is due to imperfect combustion and can generally be prevented, partially, by admitting air into the combustion chamber so as to unite with the combustion gases. There is usually in marine boilers a small door underneath the rear bridge which can be opened so as to admit the necessary amount of air.

Q. Suppose that one of a set of boilers does not get the proper amount of feed, although the check valve is sufficiently open; what might cause this trouble?

A. There are several possible causes, such as leaky joints or pipes or feed pump glands or a leaky feed relief valve. It may be that the steam pressure in this boiler is higher than in the others, or the suction may be partially closed up between the suction cock and hot well. The feed suction discharge valves may not be tight.

Q. About how many tons of coal should you expect to burn per day in six furnaces, each having a width of 3 feet and about the usual length?

A. The usual length being about 6 feet, the total grate area would be $6 \times 3 \times 6$, or 108 square feet. Each square foot will burn about 15 pounds per hour; therefore, the total number of pounds burned per hour would be 1620, and per day of 24 hours would be 38,880. Since there are 2240 pounds in a ton, the number of tons would be $17\frac{1}{4}$, nearly.

Q. How many cubic feet are occupied by a ton of coal?

A. About 35.

Q. How would you calculate the amount of stress on a boiler stay?

A. Multiply the area (in square inches) of the space supported by the stay by the pressure carried on the boiler, and divide the product by the area of the stay.

Q. How would you calculate the proper weight for a lever safety valve so that it will blow off at a given pressure?

A. See "Roper's Catechism," page 50.

Q. Suppose you have been using 8 gallons of oil a day, costing 85 cents per gallon, and you now by more careful attention to the lubricators cut down the consumption to 6 gallons per day, but you use a little better oil, costing 95 cents per gallon, what will be the difference in expense for one month?

A. The original cost per day was 85 times 8 cents, or $6.80.

The cost with the new oil is 95 times 6 cents, or $5.70.

The gain per day is $6.80 less $5.70, or $1.10.

The gain in one month is $1.10 times 30, or $33.00. (Ans.)

Q. A vessel has, in order to complete her voyage, a distance of 2100 miles to go; it actually takes 150 hours to make the run, what is the average speed per hour?

A. $2100 \div 150 = 13\frac{1}{3}$ miles per hour. (Ans.)

Q. From 7 A. M., on the 20th of June, to the 3d of August, 10 P.M., the coal consumption was 3168 tons; the distance passed over in this time was 14,784 knots; what is the average consumption of coal and average speed?

A. The time is 44 days 15 hours, or 1056 hours.
The coal consumption per hour is 3168 ÷ 1056, or 3 tons.
The coal consumption per day is 24 × 3, or 72 tons.
The speed is 14,784 ÷ 1056, or 14 knots per hour. (Ans.)

Q. If the counter stands to-day at noon at 95,321 and to-morrow at noon it stands at 98,237, what will be the average number of revolutions per minute?

A.

```
     98237              60)243(4 3/60 (Ans.)
     95321                 240
12)2916(243                ---
   24                        3
   ----
    51
    48
    ----
     36
     36
    ----
```

Q. Suppose at 10 A. M. the counter stands at 54,606, and the engine is making 60 revolutions per minute, at what time will the counter stand 100,026?

A.

```
 100026          60)757(12 hrs. 37 minutes.
  54606             60
 ------             --
60)45420(757        157
  420               120
  ---               ---
   342               37
   300
   ---
    420
    420           10.37 P. M. (Ans.)
```

Q. Suppose that an engineer receiving $[illegible]5 a week strikes for an increase of $3 per week; [illegible]e is idle for ten weeks, but at the end of that ti[illegible] receives employment at the higher rate, how lo[illegible] will it take him to make up the wages he lost whil[illegible]dle?

A. His lost wages are 15 × 10, or $150.

It will take him 150 ÷ 3 weeks, or 50 [illegible]eeks to make up for the lost time. (An[illegible])

Q. Suppose that the rate of burning per [illegible]uare foot of grate surface per hour is 20 poun[illegible], and suppose that a ton of the coal used occ[illegible]ies a space of 40 cubic feet; how many cubic [illegible]et of coal would be burned in ten hours on a [illegible]rate 6 feet by 3 feet?

A. 6 × 3 × 20 × 10, or 3600 = nu[illegible] of pounds of coal burned.

2240 pounds occupy 40 cubic feet, or 56 pounds occupy 1 cubic foot.

3600 pounds occupy 3600 ÷ 56, or $64\frac{1}{5}\frac{6}{6}$, or $64\frac{2}{7}$ cubic feet. (Ans.)

Q. You have 6 furnaces, each 6 feet long by 3 feet wide, the rate of burning is the same as the preceding question, and every pound of coal evaporates 9 pounds of water; how many tons of coal will be used in ten hours, and how many tons of water will be evaporated?

A. The area of grates is $6 \times 6 \times 3$, or 108 square feet.

The number of pounds burned per hour is 108×20, or 2160.

The number of pounds of water evaporated is 2160×9, or 19,440.

The number of tons of coal burned in 10 hours is $2160 \times 10 \div 2240$, or $9\frac{44}{224}$, or $9\frac{11}{56}$ tons.

The number of tons of water evaporated is 9 times this amount, or $86\frac{176}{224}$, or $86\frac{11}{14}$ tons. (Ans.)

Q. A vessel starts on a voyage of 1200 miles with [illegible] tons of coal; after having steamed 500 miles it is found that 30 tons of coal have been consumed. If the remainder of the voyage is made at the same rate of steaming, how much coal will be left at the end of the voyage?

A. $30 \div 5 = 6$, the number of tons used per hundred miles. Therefore, 1200 miles will require 12×6, or 72 tons. Hence, there will be 8 tons left at the end of the voyage.

Q. In 24 hours steaming the tally of baskets of coal for each watch was 100, 105, 110, 107, 104, 103. If each basket weighed 45 pounds, what would be the consumption per day in tons?

A. 100	629	2240)28305(12 tons 1425 lbs.	
105	45	2240	(Ans.)
110			
107	3145	5905	
104	2516	4480	
103	28305	1425	
629			

Q. An engineer who receives $15 per week lays aside $\frac{1}{6}$ of his pay; how many weeks will it take him to save up $250?

A. $15 \div 6 = 2\frac{1}{2}$ dollars, the amount saved per week; $250 \div 2\frac{1}{2} = 100$, the number of weeks necessary.

QUESTIONS FOR SECOND ASSISTANT ENGINEERS.

[In addition to the following, the candidate should be prepared to answer the questions for third assistant engineers.]

Q. Trace the passage of steam from the boiler, naming all the parts and valves which it passes from the time it leaves the boiler until it comes back as feed-water.

A. Steam passes from the dome or dry pipe through the stop valve into the main steam pipe;

from the main steam pipe it passes through another stop valve, through a separator, through the throttle valve into the steam chest; from the steam chest it passes through the high-pressure steam valve, through the steam port into the high-pressure cylinder. It forces the piston to the end of its stroke and then exhausts into the intermediate steam chest or into the receiver. From here it passes through the intermediate slide valve and steam port into the intermediate cylinder, expands and drives the piston to the end of the cylinder and exhausts into the low pressure steam chest where it drives the piston over by its expansion and expands into the condenser. It is there condensed and passes the foot valve into the air-pump, and then through the air-pump bucket valve and head valve into the hot well. If a surface condenser is used, the condensed steam is pumped by the feed pump through the feed pipe and relief valve through a feed water heater and through another length of feed pipe past the check valve into the boiler.

Q. What is a gusset stay, and where is it used in a boiler?

A. It is a stay made of iron plate which is carried from the front or back of the boiler to the boiler shell; it is secured at each end by means of angle irons and rivets.

Q. What is double riveting, and in what parts of the boiler is it used?

A. Double riveting consists of two rows of rivets placed either zigzag or opposite each other; the curvilinear seams are double riveted as well as the longitudinal seams in the furnace chamber and the horizontal seams of the ends.

Q. What is calking, and how is it done?

A. Calking means the closing up of the seams of boilers or iron vessels so as to make them steam- or water-tight. After the edges have been placed true and the plates riveted together, the edges are calked by a hammer and chisel, the iron being struck with the chisel in such a way as to close the joint.

Q. Describe as many different methods as you know of fastening the ends of the mainstays of the boiler, and state their relative merits.

A. First: Forked eye-bolts are tapped into the ends of the boiler and secured to them by a nut; the stay is secured at each end to them by a wrought iron pin and cotter, which prevents the pin from drawing back; this form is very convenient, as by driving out the end pins the stays can be gotten out of the way in a few moments. *Second:* The end is made larger than the body of the stay and is threaded; it is then secured to the boiler by nuts and washers inside and out. This arrangement is mechanically good, but is somewhat difficult to remove. *Third:* The ends of the stay are made with a "T" head and are fastened between a pair of angle irons with rivets and bolts.

Q. What is a rivet stay, and where are such stays commonly used?

A. A rivet stay consists of a long rivet passing through a thimble, or distance piece of iron which is placed between the plates to be stayed together. The ends of the rivets are then headed over in the usual way. The more common plan, however, is to tap both plates and thread the rivet, screwing the rivet through both plates and afterward heading the ends of the rivet over, which does away with the necessity of using the thimble.

Q. Where do boiler tubes generally leak, what are some of the causes, and how is the trouble repaired?

A. Tubes usually leak at the combustion chamber end. Leaks are caused by allowing the plates and ends of the tubes to become foul, in which case they are liable to be overheated; another cause is blowing off of boilers under steam pressure. The trouble may be repaired usually by expanding the tubes. When they are much worn they should be driven in slightly from the smoke box end and re-expanded and rebeaded.

Q. Where do the tube sheets usually crack?

What are the reasons, and what methods are employed for repairing?

A. The tube sheets generally crack in between the tubes. The cracks are caused sometimes by allowing scale to collect on the inside of the sheet or by the opening of furnace doors, which allows a current of cold air to strike the heated metal and produces contractions of the plates. One method of repairing is to cut a hole in a plate large enough to encircle the tube nearest the crack, fastening this small plate on to the boiler sheet so as to cover the crack.

Q. What part of a marine tubular boiler is the first to be injured by low water?

A. The top of the combustion chamber.

Q. Why are blow-off cocks fitted to each boiler, and how many are usually supplied?

A. The blow-off cock is fitted to the bottom of the boiler shell, so that all deposit can be blown out of the boiler at its lowest point. One blow-off cock is fitted to each boiler, and is connected by pipe to a cock or valve in the ship's bottom.

Q. At what heights are water gauge cocks placed, and must the cocks themselves necessarily be placed at these heights?

A. There are usually three cocks, one of which is placed at a height of about 3 inches above the top of the combustion chamber; the next one at the working water level, and the third in the steam space. It is not absolutely necessary that the cocks themselves should be placed at this level; they may be placed at any desired position, provided that a pipe extends from each of them into the boiler, having its open end at the heights given above.

Q. In a dead weight safety valve, how would you calculate the weight required?

A. The weight is equal to the area of the valve employed by the pressure of pounds per square inch at which the valve is to blow off.

Q. Of what should the rubbing surface of safety valves be?

A. Of brass, gun metal, or nickel, so that they will not corrode and stick.

Q. Explain in detail the construction of the glass water gauge and how it acts. To what derangements is it liable, and how are these repaired?

A. A water gauge consists of a long glass tube fixed in a brass stuffing box at each end; these stuffing boxes are usually connected together by brass columns, and the whole arrangement is attached to the boiler shell, the stuffing boxes having an opening into the boiler controlled by a valve whose stem is threaded into the boiler shell. The lower stuffing box also has a drain cock for blowing out the glass. The purpose of the gauge is to show the level of the water in the boiler, and as its bottom is in connection with the water space and its top with the steam space, the water will rise in the tube to the same height in the boiler. The principal derangements are the breaking of the glass and choking up with impurities. When the glass breaks, the two cocks which are connected with the boiler are closed, and a new glass is put in. If it becomes choked up with dirt, it may be cleaned by opening the drain cock and allowing the steam and water to rush through the glass.

Q. You will sometimes see water gauges with pipe connections to the top and bottom instead of with a direct connection into the boiler; what is this arrangement, and what is its advantage?

A. One pipe runs to the steam dome and the other to the bottom part of the boiler; the object being to prevent, so far as possible, certain disturbances in the water level in the glass, which, with the original arrangement, might be caused by priming or by the boiling of the water.

Q. Why do some steam gauges have an inverted syphon pipe below them?

A. The syphon contains water whose object is to prevent the heat of the steam from injuring the machinery of the gauge.

Q. When the syphon is used, why is a small cock put on the pipe leading to the steam gauge?

A. This cock is a drain cock on the boiler side of the syphon, placed at a level equal to the highest point to which water can rise in the other leg. Without this cock the indicated pressure will be too high, owing to the weight of the water which would collect in the boiler leg of the syphon.

Q. What is meant by the salting of a boiler, and how is it prevented?

A. Salting means allowing the water in the boiler to become very dense. It is prevented by occasionally blowing off a portion of the water in the boiler and taking in water which is less saline.

Q. What is the difference between the formation of scale and salting of the boiler?

A. Salting is the gradual increase in the density of the water owing to the salt being left behind when the water is turned into steam, whereas scale is the deposit of insoluble substances like lime and magnesia on the heating surface.

Q. What is the density of ordinary sea water, and how is it ascertained?

A. About one part of salt to 33 parts of water, or about 5 ounces per gallon. The density is ascertained by a salinometer, which consists of a float and graduated stem.

Q. At what density should boilers be worked?

A. In general, at a density not exceeding $\frac{2}{33}$, or 10 ounces of salt per gallon.

Q. What are scum cocks, and how are they arranged and used?

A. Scum cocks are cocks placed on the shells of the boiler and connected to a pipe leading to the ship's side on which a cock is placed. From the cock on the boiler shell pipes lead into the boiler and are fitted on the end with a dish or trough slightly below the ordinary water line. The scum cocks are used to remove dirt floating on the water surface and also a portion of the salt which is carried up by the steam bubbles to the surface.

Q. What is boiler scale, and what bad effects does it produce?

A. Scale is produced by deposition of the impurities contained in feed-water, and usually consists of a mixture of magnesia and lime salts and some common salt. It naturally collects at the hottest part of the boiler and causes the plates to burn, tubes to leak, and also diminishes the efficiency of the boiler.

Q. Explain how the formation of scale can be best prevented and how it is removed from the boiler.

A. It is prevented best by never wasting any steam or water in vessels which have a surface condenser. With a jet condenser frequent blowing off is employed to prevent it. When scale is accumulated it is removed by chipping it off with hammers or a long chisel.

Q. Explain how you would proceed to stop a leak from a split tube.

A. I would close the ashpit doors and drive into the tube a plug of soft wood at each end of the tube; the plugs will swell up owing to the moisture, and the tube will fill up with solid substances which will stop the leak.

Q. Describe the piston of a steam cylinder.

A. The piston usually consists of a cast-iron disc stiffened with strong ribs. The disc is turned to an accurate circle on its outer edge, having grooves in it to receive the piston rings. The piston rings are made with a slight opening and spring so that they press out against the cylinder surface and make a steam ~~pipe~~ tight joint.

Q. For what are cylinder drain cocks used, and why is a valve sometimes placed on them?

A. Drain cocks are used for blowing out any water that may collect in the cylinders through condensation or on account of priming. In the case of condensing engines a valve is fitted to them which opens outward only, the object being to allow the water to be blown without permitting any air to rush in which would impair the vacuum.

Q. Explain how a cylinder escape valve is made, and for what it is used.

A. A cylinder escape valve consists of the valve seat and valve, the latter being loaded with the spiral spring. The amount of load is regulated by means of a screw which passes through the valve cover and presses on the disc which fits on the top of the spring. The object of the valve is to form a self-acting relief which will allow any sudden accumulation of water from priming or other cause to pass out of the cylinder without damage. These valves are covered with guards or domes with an escape pipe, so that the hot water, which is ejected from them, may not be thrown over the attendant.

Q. What is the object of using multiple expansion engines?

A. In order to obtain a greater economy in coal consumption. Other things being equal, the economy depends upon the difference between the temperature at which steam is taken into the cylinder and that at which it is exhausted. Since the lowest possible temperature is that corresponding to the absolute vacuum, it is obvious that in order to make the difference of temperature great, we must admit the steam at a high pressure; but if the steam underwent its entire expansion in a single cylinder there would be a great deal of condensation in the cylinder, since the incoming high pressure steam would come in contact with comparatively cold walls; the expansion is therefore divided between two or more cylinders. A further advantage of having several cylinders is that the cranks are placed at an angle to each other, and more uniform turning moment is secured.

Q. When engines are to be stopped with steam up, what would you close and what open?

A. I would close the throttle valve and the sea injection valve, and unless I were sure that the check valves on the boilers were tight, I would shut the feed so that no water would be lost from the boilers by blowing through the check valves. I would also close the damper doors; it might be advisable also to open the safety valve.

Q. What would you do before starting?

A. I would open the drain cocks and blow steam through the cylinders and condenser so as to gradually warm them up. I would examine the valves to see that the proper ones were opened, as, for example, the feed check valves, the injection and discharge valves, and would then gradually turn the engine around.

Q. What is the racing of an engine, and what danger is attached to it? What can be done to prevent it?

A. The racing of an engine is the revolution of the engine at a very rapid rate, and is caused by the propellor coming out of water owing to the pitching of the ship. The racing causes sudden and heavy strains on the machinery, such as may cause a breakdown, unless the most careful attention is given by the engineer. A governor is often fitted to the engines. In any case I would proceed under easy steam and should cut down the supply of injection water.

Q. What kind of a governor is employed?

A. A centrifugal governor.

Q. With a surface condenser, what valves should be open some time before starting an engine?

A. The main stop valve and the main check valves to the boiler, the sea inlet for the circulating water, and all drain cocks on the cylinders and jackets. The discharge valves should be examined to see if they are free to lift.

Q. What is a steam jacket, and why is it used? With what engines are they generally found?

A. The steam jacket is a casing around a cylinder, leaving a hollow space between it and the cylinder, which is kept supplied with steam from the boiler. The object of a steam jacket is to prevent, as far as possible, condensation in the cylinder. Jackets are generally found with multiple expansion engines. They are covered with felt or some other non-conductor to prevent the radiation of heat.

Q. What cocks are found on steam jackets, and why?

A. The steam jacket is supplied with a steam cock for turning on and shutting off steam from the boiler, and also with drain cocks, so that any accumulation of water in the jacket may be blown off into the hot well.

Q. Name the principal pipes used with the engines and boilers of a steamer, and tell to what the ends of the pipes are connected.

A. The main steam pipe connecting the stop valve on the boiler to the steam chest on the engine. Donkey steam pipe connecting the donkey stop valve of the boiler to the donkey steam chest. Cylinder jacket pipe running from the boiler to the jacket of the cylinder. Steam whistle pipe, pipes for any engines, or winches on deck; a feed pipe connecting boiler with the feed pumps. Circulating water pipe connecting the inlet on the vessel's side with the circulating pump; feed suction pipes connecting suction of the pumps and the hot well. A pipe connecting the air pump discharges with a valve on the ship's side and the hot well. Cylinder drain pipes connected to the drain cocks and the hot well; blow-off and scum pipes connecting the cocks on the boiler to cocks on the ship's side.

Q. Trace the passage of the circulating water for the surface condenser through the valves and pipes that it passes.

A. The water is taken from the sea through a valve on the ship's side, passes through or around the condenser tubes to the foot valve of the circulating pump, then through the pump, cylinder, and head valve, and back through the discharge valve on the ship's side.

Q. What is the path of steam from the boiler until it gets back to the hot well?

A. It passes through the main valve on the boiler, the main steam pipe and separator, if any, the throttle valve, valve chest, through the cylinder or cylinders, through the exhaust pipe into the surface condenser, and then falls to the bottom of the condenser in the form of water; from there it is taken from the air pump and discharged into the hot well.

Q. What is atmospheric pressure, how is it measured, and what is its average value?

A. Atmospheric pressure is the pressure due to the weight of the air. It varies with the height above sea level, having a value of about 14.7 pounds at sea level and growing less as the height increases. It is measured by means of the barometer.

Q. What is absolute pressure, and is absolute pressure shown by the steam gauge?

A. Absolute pressure is the pressure above a perfect vacuum. The steam gauge which under the pressure of the atmosphere only reads zero does not measure the absolute pressure in the boiler. To obtain the absolute pressure it is necessary to add the atmospheric pressure (about 14.7 pounds) to the reading of the steam gauge.

Q. What is a barometer, and for what is it used?

A. A barometer is an instrument consisting of a glass tube, sealed at its upper end, properly graduated and partially filled with mercury. It is inverted with its lower end immersed in a vessel of mercury. It is employed to measure the pressure of the atmosphere; the greater the pressure of the atmosphere the higher does the column of mercury stand in the tube.

Q. Can a barometer be used instead of a vacuum gauge?

A. Yes; the top of the tube being connected to the condenser instead of being sealed up. The height of the column then indicates vacuum in the condenser instead of atmospheric pressure.

Q. Are the indications of both steam and vacuum varied by changes in the barometer, and if so, why?

A. Yes; if, for example, the reading of the barometer changes from 29 to 31 inches this would correspond to a change in atmospheric pressure of one pound, so that the steam gauge will read one pound too little and the vacuum gauge one pound too much, since the position of the needle depends upon the difference between the pressure to be measured and the atmospheric pressure.

Q. When the reading of the vacuum gauge is 20 inches, what will be the vacuum in the condenser? Explain how you arrive at this result.

A. 20 inches corresponds to a pressure of 10 pounds, and this is the difference in pressure between the atmosphere and the pressure in the condenser; since the pressure of the atmosphere is 14.7, the pressure in the condenser will be 14.7 minus 10, or 4.7 pounds.

Q. Explain the construction of the thermometer, and state for what it is used.

A. A thermometer usually consists of a small glass bulb communicating with a fine glass tube; air is exhausted from the tube which is partially filled with mercury. When it is exposed to heat the mercury expands and rises in the tube, which is graduated. In the English or Fahr. scale the position at which the mercury stands when surrounded by melting ice is marked 32; when immersed in boiling water it is marked 212. The intervening space between these two marks is divided into 182 equal parts, called degrees.

Q. A water ballast donkey pump has a diameter of 7″ stroke of 15″ and is double acting, making 120 revolutions per minute. The cylinder is one-third empty each stroke. How long will it take to pump out 125 tons?

A. The quantity of water pumped per stroke is $7 \times 3\frac{1}{7} \times \frac{15}{3}$ cubic inches, or 110 cubic inches. $7^2 \times .7854 \times 10$ or 384.8 cu. ins.

The quantity per minute is 110×240, or 26,400 cubic inches.

125 tons $= 125 \times 2000$ pounds.

$125 \times 2000 \div 62\frac{1}{2}$ or $4000 =$ number of cubic feet in 125 tons.

$4000 \times 1728 \div 26{,}400 =$ number of minutes required $= 261\frac{29}{66}$. (Ans.)

Q. A coal bunker 6′ 9″ wide at the top and 5′ 3″ at the bottom has a length of 20′ 3″ and is 8′ high; how many tons of coal will it contain?

A. The mean width is one-half 6′ 9″ + 5′ 3″, or 6 feet.

The cubic contents are $6 \times 8 \times 20\frac{1}{4}$, or 972 cubic feet.

At 40 cubic feet per ton the number of tons will be $972 \div 40 = 24\frac{12}{40}$, or $24\frac{3}{10}$ tons.

Q. What will be the cost in dollars of a sheet of lead 12′ 9″ long by 8′ 4″ broad by $\frac{1}{4}$″ thick, at 9 cents per pound, the weight of a cubic foot of lead being $691\frac{2}{10}$ pounds?

A. 12′ 9″ = 153″ ; 8′ 4″ = 100″. The number of cubic inches is $153 \times 100 \times \frac{1}{4}$, or 3825 cubic inches.

The weight of a cubic inch of lead is $691\frac{2}{10} \div 1728$, or $\frac{4}{10}$ pound.

The total weight of the lead is $3825 \times \frac{4}{10}$, or 1520 pounds.

The cost is 1520×9 cents, or 13,680 cents $= 136\frac{8}{10}$ dollars. (Ans.)

Q. A spring-loaded safety valve has a waste pipe 20 feet high. If it became filled with water, what extra pressure would be on the valve?

A. $\frac{434}{1000}$ pound is the pressure due to 1 foot, 20 feet will cause $\frac{434}{1000} \times 20$, or $8\frac{68}{100}$ pounds pressure. (Ans.)

Q. A tank 2′ 3″ high, 2′ 6″ wide, and 3′ 9″ long has 90 gallons of oil in it ; how far from the top is the oil?

A. 2′ 3″ = 27″; 2′ 6″ = 30″; 3′ 9″ = 45″.

$90 \times 231 = 20{,}790$ = number of cubic inches in 90 gallons.

$45 \times 30 = 1350$ = number of square inches in bottom of tank.

$20{,}790 \div 1350 = 15\frac{54}{135}$, the number of inches the oil will rise in the tank.

$30 - 15\frac{54}{135} = 14\frac{81}{135}$, the number of inches the oil is from the top.

Q. Subtract 1′ $2\frac{7}{8}$″ from 2′ $2\frac{3}{4}$″ and multiply remainder by 8.

A. 2′ $2\frac{3}{4}$″ = 2′ $2\frac{6}{8}$″ $11\frac{7}{8}$″

1′ $2\frac{7}{8}$″   8

$11\frac{7}{8}$″.   95″. (Ans.)

Q. If there are two bunkers each 5′ 6″ wide by 14′ 3″ high, what length must they have so as to contain 80 tons of coal? State how many cubic feet you allow per ton.

A. $5\frac{1}{2} \times 14\frac{1}{4} = 78\frac{3}{8}$ = number of square feet in each.

$2 \times 78\frac{3}{8} = 156\frac{3}{4}$ = number of square feet in both.

At 40 cubic feet per ton, 80 tons will occupy 3200 cubic feet.

$3200 \div 156\frac{3}{4}$ = 20′ $3\frac{1}{16}$″ nearly. (Ans.)

Q. Add together the following: 18′ $3\frac{1}{4}$″; 3′ $9\frac{1}{2}$″; 14′; 3′ $7\frac{7}{16}$″; $2\frac{5}{32}$″; 7′ $3\frac{9}{32}$″.

A.

18′ $3\frac{1}{4}$″	= 18′ $3\frac{8}{32}$″
3′ $9\frac{1}{2}$″	= 3′ $9\frac{16}{32}$″
14′	= 14′
3′ $7\frac{7}{16}$″	= 3′ $7\frac{14}{32}$″
$2\frac{5}{32}$″	= $2\frac{5}{32}$″
7′ $3\frac{9}{32}$″	= 7′ $3\frac{9}{32}$″

47′ $1\frac{20}{32}$″ = 47′ $1\frac{5}{8}$″.

Q. How many tons will be contained in a bunker 25′ long, 18′ 6″ high, having a width at the bottom of 19′ and at the top of 21′?

A. The mean width is 20 feet. The cubic contents will be $20 \times 25 \times 18\frac{1}{2}$, or 9250 cubic feet.

At 40 cubic feet per ton the number of tons will be $9250 \div 40$, or $231\frac{1}{4}$ tons. (Ans.)

Q. The broadest part of the coupling bolt has a diameter of $3\frac{3}{16}''$, the diameter of the narrowest part is $2\frac{7}{8}''$, the length is $7\frac{1}{4}''$; what is the taper per foot?

A. $3\frac{3}{16}'' - 2\frac{7}{8}'' = \frac{5}{16}''$.

$\frac{5}{16} \div 7\frac{1}{4}$ = the taper per inch.

$\frac{5}{16} \times 12 \div 7\frac{1}{4}$ = the taper per foot.

$\frac{5}{16} \times 12 = \frac{60}{16}$ or $\frac{15}{4}$.

$7\frac{1}{4} = \frac{29}{4}$; $\frac{15}{4} \div \frac{29}{14} = \frac{15}{29}$ of one inch, or a little over $\frac{1}{2}''$. (Ans.)

Q. What is $\frac{3}{8}$ of $\frac{9}{16}$?

A. $\frac{27}{128}$.

QUESTIONS FOR FIRST ASSISTANT ENGINEERS.

[In addition to these the candidate should be prepared to answer the questions for third and second assistant engineers.]

Q. Suppose you were put in charge of the engines of a boat you were never on before and that you had a day's time before starting, what would you do on going into the engine room?

A. I would trace all pipes and connections to find out whence they come and where they lead, and would examine all the cocks and valves in these connections ; I would then examine the boiler, carefully taking off all the doors and going inside to examine the stays and their fastenings and the tubes and flues, taking a hammer with me to sound the boiler plates ; I would then take the furnace bars out and the bridge down and go into the combustion chamber so as to examine carefully the ends of the tubes ; I would then inspect all the valves and cocks on the boiler ; next I would examine the engines, looking at the piston and valve gear and at all parts where there is any friction ; I would then examine the condenser and the valves of all pumps ; finally, I would examine the shaft and its bearings and the stuffing box.

Q. Explain in detail what occurs to coal when it is burned in a boiler, tracing its passage from the furnace door to the stack.

A. Coal is thrown through furnace doors on the fire ; the heat of the fire liberates the hydrogen and hydrocarbon gases from the coal, and this as well as the pure carbon mixes with the oxygen that is contained in the air coming up through the grate bars ; these mixed gases burst into flame in the furnace and the products of combustion pass through the tubes and flues, giving up a large amount of their heat to the water in the boiler ;

the products of combustion then pass into the up-take and funnel and escape to the outside air.

Q. Where would you expect to find thin plates in a boiler, and how would you detect the thinness?

A. Plates usually become thin by wear in the ashpits, at the back of the combustion chamber, in the shell at the water line, and a little above the line of the fire bars in the furnace. A thin plate can be detected generally by sounding with a hammer; small holes can also be drilled at any part that is suspected and of course afterward plugged up.

Q. How are boiler tubes "fixed?"

A. They are driven from the smoke box end through both tube plates until they project a little over $\frac{1}{4}$ of an inch into the combustion chamber and remain about $\frac{1}{2}$ inch outside of the tube plate at the smoke box end; the tubes are then expanded either by tapered drift or by a tube expander. The ends of the tubes in the combustion chamber are then beaded over, while those at the other end are sometimes left without beading, so that in case of leakage the tubes may be driven in and beaded again.

Q. What is a superheater, and how is it constructed?

A. A superheater is an apparatus placed in the up-take or at the base of the funnel, so arranged that the products of combustion pass around and through it before they escape up the chimney. Its purpose is to impart an additional amount of heat to the steam from the boiler before it passes to the engine. A simple form of superheater consists of a wrought-iron drum built with tubes; the products of combustion pass through the tubes and around the shell, the steam being inside the drum.

Q. What fittings should a superheater have?

A. It should have a valve for cutting off steam connection from the boiler and also from the engine. It should also have a by-pass, so that the superheater may be thrown out of action. It also requires a safety valve and a gauge glass, the latter being for the purpose of showing whether the superheater is clear of water, as excessive priming may sometimes fill it.

Q. What causes a draught in a funnel?

A. The difference in weight between the hot gases in the funnel and the weight of a column of external air of the same volume.

Q. The draught is sometimes checked,—what is the cause of it? What symptoms would you notice, and how would you remedy the trouble?

A. The draught is sometimes checked by a downward current of air meeting the upward rush of hot air as it ascends the chimney, the action being accompanied by a buzzing noise. This down draught is the result of the admission through the furnace of too small a quantity of air to supply the exhaust, due to the ascending column of hot air in the funnel; the down draught can therefore be stopped by partially closing the damper and opening the fire doors.

Q. What parts of a steam plant should be covered with non-conducting covering, and why?

A. The boiler, the up-takes, base of the funnel, all steam pipes, the cylinders, the heaters, separators, and, in general, all apparatus that has steam inside of it. The object of a covering is to prevent, so far as possible, the radiation of heat. Such radiation would not only make the boiler and engine room excessively hot, but would also result in the waste of fuel.

Q. What substances are used for making non-conducting coverings?

A. Asbestos, hair felt, mineral wool, and magnesia are the most common.

Q. Do steam gauges indicate the total pressure of the steam?

A. Steam gauges indicate the pressure of steam above the atmosphere only, and their indications are therefore about 14.7 pounds below the value of the total pressure.

Q. For what purpose is a salinometer used, and how is it constructed ?

A. A salinometer is an instrument used to find out the density of water. It consists of a weighted bulb attached to a graduated stem.

Q. Explain the action of the salinometer and how it is graduated to read.

A. The salinometer indicates the amount of salt or other matter held in solution in the water by the depth to which it sinks. The fresher the water, the lower it will sink. It is graduated in 32ds, each 32d representing about 5 ounces of salt per gallon of water.

Q. What is necessary in order that the salinometer give correct indications ?

A. It must be used at the temperature at which it is marked.

Q. Suppose that the check valve of one of a set of boilers should have a piece broken off the valve, what trouble would this cause, and what would you do to remedy it ?

A. The boiler whose check valve is broken would get more than the proper amount of the feed water, while the other boilers would have a great difficulty in getting sufficient amount. To remedy this, I would close the broken valve partially and, if possible, would open up the other valves more than before.

Q. In modern marine engines, when a link motion is not used, what takes its place?

A. Some patent valve gear, such as Joy's.

Q. What causes the friction on a slide valve, and how can the amount of this friction be reduced?

A. The friction is caused by the action of the steam on the unbalanced area of the slide valve, pressing it against the valve seat with a force that is equal to this area multiplied by the steam pressure. This friction can be diminished by relieving the back of the valve from the steam pressure; this is accomplished by forming a vacuum or exhaust steam pressure space at their backs by means of a brass packing held up to the valve with springs or india-rubber. This space is put into communication with the condenser or exhaust, and therefore a pressure equal to the vacuum tends to lift the valve from its seat.

Q. Explain how you could measure the travel of the eccentric rod.

A. The travel of the eccentric rod is the distance moved by the rod on the up or down-stroke. If the sheave be off, the travel can be measured by measuring the distance between the shaft opening and the center of the eccentric disc; this multiplied by 2 will give the travel of the rod. If the sheave cannot be conveniently taken off the shaft the travel can be measured in this way: Subtract the width, of the thickest part of the sheave from the broadest part, and the remainder will be the full travel.

Q. Explain the construction of the surface condenser.

A. A surface condenser consists of an iron box containing a large number of tubes; these tubes may be either horizontal or vertical, and are made of brass. At each end of the tubes are tube plates through which the tubes pass,—there is often a supporting plate in the middle. At each end of the condensers are doors or openings, so that the ends of the tubes may be examined or repaired when necessary. In some cases steam is admitted to the tubes, and the injection water passes around the outside of the tubes; in other cases steam is led into the space around the tubes, and water passes through them, the latter practice being the more general.

Q. Suppose that a tube splits, what would you do?

A. I would drive in a wooden plug at each end, and keep it there until I had an opportunity of taking out the tube and replacing it with a new one.

Q. Where do surface condensers become foul, and how are they cleaned?

A. Surface condensers become foul both on the inside and outside of tubes. The outside of the tube has a deposit owing to the salt water; the steam side of the tube fouls owing to the action of the grease and oil that are in the steam coming from the cylinders. The condensers are cleaned by scalding them with hot water taken from the boiler with a hose. Caustic soda is also generally used.

Q. What is a vacuum, and with what apparatus is it produced?

A. A vacuum is a space devoid of pressure. It is impossible to produce a perfect vacuum, but a partial vacuum is produced by means of a condenser and air pump.

Q. Explain how you would proceed to produce a vacuum with a jet condenser.

A. I would first open the blow-through valve, allowing the steam to blow out all air and water in the condenser and at the same time to warm the condenser up; as soon as steam issues from the snifting valve I would shut the blow-through valve and open the injection cocks; the cold water will then mix with the steam, condense it and form a vacuum. As soon as the gauge shows a sufficient vacuum I would shut off the injection cocks, so as to prevent the condenser's filling.

Q. Explain the method of operation if the condenser were of the surface type.

A. Some time before starting I would open the injection valve, so that the circulating water might enter the injection tubes and cool them; then as soon as the engines are started the steam coming in contact with these cold tubes will be condensed, and after the first two or three turns of the engine the condenser will be clear.

Q. How is the vacuum maintained?

A. By the constant condensation of the used steam by means of cold water or cold tubes and by constant clearing of the condenser by the air pump.

Q. Why does the condensation of steam make a vacuum?

A. Because a cubic foot of steam when condensed into the form of water occupies only about one cubic inch of space.

Q. What is the advantage of a surface condenser over the jet condenser?

A. The injection water is not mixed with the water of condensation; the boilers are therefore at all times supplied with fresh water, thus preventing the formation of scale, increasing the durability of the boiler, and making a saving in the consumption of fuel.

Q. Explain the meaning of the terms "injection water" and "water of condensation."

A. "Injection water" is the water introduced into the condenser for the purpose of condensing the steam; "water of condensation" is the water resulting from the condensation of the steam itself.

Q. About how much injection water is necessary to condense steam?

A. About twenty-five times the amount of the water of condensation.

Q. Has the air pump as much duty to perform in the case of surface condensers as with jet condensers?

A. No; with surface condensers the air pump has only to extract the air and the water of condensation; in the case of the jet condensers it has not only to extract this, but also the injection water.

Q. How is the amount of vacuum in the condenser determined?

A. By the vacuum gauge.

Q. What is the meaning of "a reading of 16 inches on the vacuum gauge?"

A. Two inches of mercury corresponds closely to 1 pound of vacuum; therefore 16 inches of mercury represents 8 pounds vacuum,—that is to say, a pressure 8 pounds less than atmospheric pressure, or a pressure of about 6.7 pounds absolute.

Q. What is a circulating pump? For what purpose is it used, and how is it driven?

A. A circulating pump is one used to cause water from the sea inlet to circulate through the condenser tubes; it is operated sometimes by a lever connected to the main engine, and in other cases by means of an independent engine.

Q. Why is an air valve sometimes fitted to a circulating reciprocating pump?

A. So that the air will tend to obviate the solid resistance that would otherwise be offered by the water.

Q. Explain the difference between a bucket air pump, a piston air pump, and a plunger air pump.

A. A bucket air pump has a brass piston packed with a spun-yarn gasket to keep it tight; the body of the bucket has perforations allowing water to pass through on the down stroke. The action of the pump is as follows: On the down stroke the water rushes through the perforations of the bucket, and as soon as the up-stroke begins the weight of the water forces down the india-rubber valve; the bucket lifts the water up and discharges through the head valve the water that was taken in through the bucket on the down stroke; at the same time a vacuum is created on the under side of the bucket, into which the condensed water and air flow from the condenser ready to be taken by the bucket on the next down stroke.

A piston air pump, usually a double-acting pump, has suction and delivery valves at both ends. The bucket in this case is solid, and the water is taken and forced out of the pump on both the outward and return strokes.

A plunger air pump has a solid plunger or ram working through a bushing.

Q. When the condenser is working and the air pump bucket is at the top of its stroke, at what height will the water stand in the condenser, as compared with the level of water in the air-pump chamber?

A. The comparative level in the two places depends upon the intensity of the vacuum existing in the two places, that in the chamber being always the best. If the vacuum in the pump were 29 inches and that in the condenser 28 inches, the difference in vacuum would be 1 inch or $\frac{1}{2}$ pound, which corresponds to a difference in level of water of 1.1 feet, so that the level in the condenser would be that amount below the level in the pump.

Q. With a surface condenser and single-acting air pump, what would be the effect of a leaky foot valve? What would be the effect of a leaky bucket if there is also a foot valve?

A. Provided the foot valve is sufficiently immersed in water, its leaking will not affect the working of the pump ; the effect of a leak in the bucket depends upon whether the pump is working to its full capacity. In ordinary cases the air pump never works anywhere nearly full of water. Suppose that the pump ought to lift, say, one gallon of water each stroke and by reason of the leak one-half gallon passed back, then the water would rise in the condenser high enough so that the bucket would lift one and one-half gallons; but as one-half would be allowed to pass back through the leak, the proper amount of one gallon would be actually left at each stroke. In case the pump were working at its full limit and the bucket were leaky, the condenser would gradually fill up.

Q. What is the temperature at which water usually stands in the hot well? What would be the effect of temperature lower or higher than this amount?

A. The temperature usually varies from 110 to 130 degrees. A higher temperature than this is liable to cause a deterioration of valves, and a lower temperature will produce an increase in the consumption of fuel.

Q. How could you tell whether the inlet valve of the circulating pump were open to the proper amount?

A. By the vacuum gauge and by the condenser.

If the valve is open too little, the condenser will get hot and a low vacuum will result; if the valve is too far open, the condenser will get too much water and will become cold, although the gauge will show a good vacuum.

Q. What is the object of placing a pet cock or valve on the feed pump, and where should it be placed?

A. It should be placed above the suction valve of the pump; it enables the engineer to see if the engine is working, and also it forms an air cushion which prevents heavy knocking in the pump.

Q. How are the ends of surface condenser tubes fastened?

A. One method is to tap the holes in the tube sheet for a part of the thickness; after the tube is put in place, a packing is inserted around it, and a brass ferrule is screwed in which forces the packing up against the tube. Another method is to make use of a wood ferrule fitting around the tube which is driven into the tube plate.

Q. What is a snifting valve, and where is it placed and what is its purpose?

A. A snifting valve is a small relief valve which is placed on the bottom of the condenser. It is arranged in such a way that the vacuum in the condenser keeps the valve closed, and in case of an excessive pressure in the condenser the valve will open and relieve it. Such valves are not always used now, especially with compound engines, as the necessity of starting with a good vacuum is not so great as with simple engines.

Q. What is cushioning in a steam cylinder? What produces it and what advantage is it? Does the amount of the exhaust pressure affect it?

A. Cushioning is caused in the cylinder by the closing of the exhaust before the piston has completed its stroke. The advantage lies in the production of a sort of cushion owing to the elasticity of the compressed steam, which takes off from the piston the heavy knock that would otherwise take place at the end of a stroke. The amount of cushioning depends upon the exhaust lap and the back pressure, increasing if either of these are increased.

Q. About what vacuum should the vacuum gauge show when the engines are working all right, and to what absolute pressure does this correspond?

A. About 27 inches. This corresponds to a pressure of about 13½ pounds below the atmosphere, or about 1.2 pounds absolute.

Q. What is the extreme height to which, theoretically, water can be drawn by a suction pump, and how does this compare with the result obtained in practice?

A. The extreme vertical height is about 34 feet. In practice it is difficult to exceed 26 feet.

Q. What is a vacuum? Can it move a piston?

A. A vacuum is a space devoid of pressure. A vacuum cannot, strictly speaking, move a piston. It is the preponderance of the atmospheric pressure above that of the vacuum which moves the piston.

Q. When the temperature of the water in the condenser is 212 degrees, what is the vacuum in the condenser?

A. There is no vacuum in the condenser, because the water will boil at that temperature and give off steam that will have a pressure equal to the atmospheric pressure.

Q. What is the temperature of the following: (1) Melting ice; (2) the hot well; (3) boiling water; (4) steam at 60 pounds gauge pressure; (5) steam at 100 pounds; (6) steam at 135 pounds; (7) the hot gases in the funnel?

A. Melting ice, 32 degrees Fahr.; hot well, 120 degrees; boiling water in open air, 212 degrees; steam at 60 pounds, 307 degrees; steam at 100 pounds, 338 degrees; steam at 135 pounds, 358 degrees; hot gases, from 600 to 700 degrees.

Q. What are the effective heating surfaces in a marine boiler? Are the vertical surfaces as efficient as horizontal?

A. The effective heating surfaces of a marine boiler are those portions situated above the fire bars which are exposed to the heat of the flame and the products of combustion. Vertical surfaces are much less efficient than horizontal.

Q. In what ways could you ascertain the pressure in a steam boiler?

A. The ordinary method is, of course, by the reading of the steam gauge. If this were out of order an approximate determination of the pressure could be made by seeing at what position the safety valve would blow off. If neither of these were available, a still rougher method would be to take a bottle containing a thermometer and blow off steam from one of the gauge cocks into the bottle. After the thermometer has reached its maximum reading I would find from tables what pressure of the steam corresponded with the temperature shown by the thermometer.

Q. How could you test the trueness of the propeller shaft without lifting it?

A. I would slacken the coupling bolts and see if the distance between the edges of the couplings is the same all around ; I would stretch a line horizontally along the shaft and measure from it to the sides of the couplings ; if they are of the same diameter all the distances should be the same.

Q. Suppose the air-pump rod should break and you had no extra rod on board or nothing with which you could make one, what would you do?

A. The condenser ought to be arranged with a by-pass, so that by means of valves it could be shut off and the engine run non-condensing. If there is no by-pass, I would rig up a temporary exhaust pipe and run non-condensing.

Q. Suppose that the cylinder head cracked or broke, what would you do?

A. I would endeavor to repair it with iron; or, if I had no suitable pieces of iron, I would strengthen it with plank and ropes or wire; if it was impossible to do this, I would, of course, draw my fires and let the boat go under sail.

Q. Suppose the crank pin should break, what would you do?

A. I would remove it and replace it with a new one if there was one on board; if not, it would be necessary to detach the propeller shaft and go under sail.

Q. Suppose the cut-off mechanism should be broken at one end, what would you do?

A. If I could not readily repair it I would remove the mechanism from the other end also and would work the engines full stroke.

Q. Examine the following indicator cards and state what faults they show in the engines.

A. See "Roper's Engineers' Handy Book," pages 545–548.

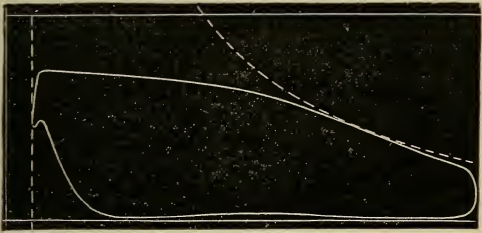


Diagram from simple slide valve engine, 16″ x 30″.

Diagram from 18″ x 36″ engine with cut-off valve operated by Kendal Governor.

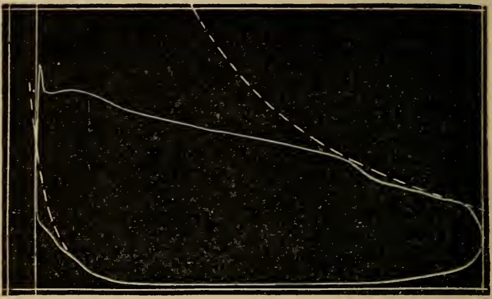


Diagram from simple slide valve engine, 9″ x 15″.

Diagram from same, 9″ x 15″ engine, with different valve setting.

Q. A certain surface is 14′ $3\frac{3}{4}''$ long by 7′ $1\frac{1}{2}''$ broad; what is the area in square feet and decimals of a square foot?

A. 14′ $3\frac{3}{4}'' = 14.3125'$; 7′ $1\frac{1}{2}'' = 7.125'$.
$14.3125 \times 7.125 = 101.9765625'$. (Ans.)

$$
\begin{aligned}
3'' &= \tfrac{1}{4}' \text{ or } .25' \\
\tfrac{3}{4}'' &= .75'' \text{ or } \underline{.0625'} \\
3\tfrac{3}{4}'' &= \phantom{.75'' \text{ or }} .3125' \\
1\tfrac{1}{2}'' &= 1.5'' \text{ or } .125'
\end{aligned}
$$

```
   14.3125
    7.125
   -------
   715625
  286250
 143125
1001875
----------
101.9765625
```

Q. An oil tank 3′ long by 2′ broad has a height of 3′. On Wednesday the height of the oil is noted in the glass gauge, and on the following Tuesday at the same hour the height is again noted, the difference in height being $8\frac{1}{2}''$; what is the average consumption per day in gallons and decimals of a gallon?

A. $3 \times 2 \times 144$, or $864 =$ area in square inches of floor of tank.

The time from Wednesday to Tuesday is 6 days.

The number of cubic inches of oil used is 864×8.5, or 7344.

The number of gallons is $7344 \div 231$ and the number of gallons per day is one-sixth of this.

```
      6)7344
  231)1224(5.299 nearly.  (Ans.)
      1155
        690
        462
       2280
       2079
        201
```

Q. How long will it take to pump out a tank 30′ by 20′ 3″ by 6′ 4″? The diameter of the pump, which is double acting, is 8″ and its stroke is 10″; the pump makes 70 revolutions per minute; the pump is $\frac{9}{10}$ full at each stroke.

A. The volume of the tank is $30 \times 20\frac{1}{4} \times 6\frac{1}{3}$, or 3847.5 cubic feet.

The amount of water per stroke is $.7854 \times 8 \times 8 \times 10 \times \frac{9}{10}$, or 452.39 cubic inches.

The amount of water per minute is $452.39 \times 70 \times 2 \div 1728$, or 36.65 cubic feet.

The number of minutes required is $3847.5 \div 36.65$, or 104.98 minutes. (Ans.)

Q. What is the approximate weight of a cast-iron piston 18″ diameter and 2″ thick? What weight do you allow per cubic foot for the cast iron?

A. The volume of the piston is $.7854 \times 18 \times 18 \times 2$, or 508.9392 cubic inches.

$508.9392 \div 1728 =$ the number of cubic feet.

Allowing 450 pounds per cubic foot, the weight will be $\frac{508.9392 \times 450}{1728}$, or 132.53. (Ans.)

Q. A scale of iron rust which you have taken off weighs 10 ounces; the composition of rust is 112 parts by weight of iron to 48 parts oxygen; how many ounces of iron was in this scale?

A. The amount of iron is $\frac{112 \times 10}{112 + 48} = \frac{1120}{160}$ $= 7$ ounces. (Ans.)

Q. Suppose that a bar of iron has a weight of one ton suspended on it, and it is found to stretch one inch in 12,000; what will be the stretch of a similar bar whose length is 20′ if a weight of 10 tons is suspended upon it?

A. With 10 tons suspended on it instead of 1 ton, the bar would stretch 10 inches in 12,000, or $\frac{1}{1200}$ of its length. $\frac{1}{1200}$ of 20 feet is $\frac{240}{1200}$ of 1 inch. $\frac{240}{1200}$ of an inch $=$ .2 inch. (Ans.)

Q. There are 275 tons of coal in the bunkers, the average percentage of ash being 15 ; how much actual fuel is there in the bunkers?

A. If the ash is 15 per cent., the actual amount of coal is 100 — 15, or 85 per cent.

```
   275
   .85
  ----
  1375
 2200
 ------
233.75 tons. (Ans.)
```

Q. What is the square of 271.6? What is the cube of 54.3?

A.

```
   271.6
   271.6
   -----
   16296
   2716
  19012
  5432
  -------
73766.56 (Ans.)
```

```
      54.3
      54.3
      ----
      1629
     2172
    2715
   -------
   2948.49
      54.3
   -------
    884547
  1179396
 1474245
 ----------
160103.007 (Ans.)
```

Q. A tank in a steamer 20′ 6″ diameter by 22′ 3″ deep is to be used for a coal bunker, but the bottom to the height of 4′ cannot be used for coal ; how many tons of coal can be put in the tank, and how long will it last if the average rate of consumption is 40 tons per day?

A. The area of the tank is $.7854 \times 20.5 \times 20.5$ square feet.

The space available for coal has a depth of $22' \ 3'' - 4' = 18' \ 3''$, or 18.25 feet.

The volume in cubic feet is $.7854 \times 20.5 \times 20.5 \times 18.25$, or 6023.4125.

```
  .7854
   20.5
  ------
  39270
 15708
 --------
 16.10070
 20.5
 ----
  805
 322
 ------
 330.05
```

```
   330.05
    18.25
   ------
   165025
   66010
  264040
  33005
 ---------
 6023.4125
```

```
40)6023.4125(150.5853 tons.
   40
   ---
   202
   200
   ---
     234
     200
     ---
      341
      320
      ---
       212
       200
       ---
        125
        120
        ---
          5
```

```
40)150.5853(3.7646 days.
   120
   ---
    305
    280
    ---
     258
     240
     ---
      185
      160
      ---
       253
       240
       ---
        13
```

```
 .7646 days          .3524 hours
    24                  60
 -----              ----------
 30584              21.1440 minutes.
15294
-------               .144 minutes
18.3524 hours.          60
                      -----
                      8.640 seconds.
```

Answer: The coal will last (assuming that a ton occupies a space of 40 cubic feet) 3 days, 18 hours, 21 minutes, and 8.64 seconds.

Q. What is the sum of $\frac{3}{22}$ and $\frac{7}{19}$ in decimals?

A.

$$\frac{3}{22} = .13636$$
$$\frac{7}{19} = .36842$$
$$.50478 \text{ (Ans.)}$$

```
22)3.00000(.13636        19)7.00000(.36842
   22                       57
   --                       --
   80                       130
   66                       114
   ---                      ---
   140                       160
   132                       152
   ---                       ---
     80                        80
     66                        76
     ---                       --
     140                       40
     132                       38
     ---                       --
       8                        2
```

Q. An engine after being compounded generated 20 per cent. more power from the same amount of fuel (10 tons a day); how many tons of coal will be used if the engine be worked compounded at the original power?

A. If we call the old power 100 per cent., the new power will be 120 per cent. Then 120 : 100 = 10 : number of tons which will be used.

$$10 \times 100 \div 120 = 8\tfrac{1}{3} \text{ tons. (Ans.)}$$

Q. If the coal consumption is 30 tons a day, and if each of the six watches throws away 36 baskets of ashes weighing 50 pounds each, what percentage of the fuel is ash?

A. $36 \times 50 = 1800$ pounds, the ash per day.
$2240 \times 30 = 67{,}200$, the total number of tons of fuel burned per day.

$$\begin{array}{r} 67200)1800.000(.027 \text{ nearly.} \\ 134400 \\ \hline 456000 \end{array}$$

$.027 = 2.7$ per cent. (Ans.)

Q. A cylinder has a diameter of 30″. The packing ring is too large and a piece $\frac{9}{16}$ of an inch is cut out of it; then when it is put in place there is an opening of $\frac{1}{32}$ in the ring; what is the difference between the diameter of the cylinder and diameter of the ring before it was cut?

A. The circumference of the inside of the cylinder is $3.1416 \times 30 = 94.248''$.

$\frac{1}{32}'' = .03125''$.

$\frac{9}{16}'' = .5625''$.

$94.248'' - .03125'' + .5625''$ is the diameter of the ring before it was cut.

Therefore the difference between the diameter of the cylinder and that of the ring is $(94.248 - .03125 + 5625) - 94.248$, or $.5625 - .03125$ inch $= .53125''$. (Ans.)

Q. What is the horse-power of an engine whose cylinder is 36″ in diameter, whose stroke is the same and which makes 40 revolutions per minute if the mean effective pressure is 40 pounds?

A.

```
      .7854           3
         36          40
     ------          ---
      47124         120
     23562           40
     ------         ----
    28.2744        4800
         36           2
    -------        ----
    1696464        9600
    848232
   ---------
  1017.8784

        1017.88
           9600
       --------
       61072800
       916092
      ---------
33000)9771648.00(296 horse-power. (Ans.)
      66000
      ------
      317164
      297000
      ------
       201648
       198000
       ------
         3648
```

The area of the piston is .7854 × 36 × 36, or 1017.8784 square inches.

The horse-power is equal to the area × $\frac{36}{12}$ × 40 × 2 × 40 ÷ 33,000, or 296 horse-power. (Ans.)

Q. What is the proportion between the area of an 8″ steam pipe and of a cylinder of 40″ diameter?

A. The areas are in proportion to the squares of the diameters and are therefore as $8 \times 8 : 40 \times 40$, or as $64 : 1600$, or $1 : 25$.

Q. If the feed-water has $4\frac{1}{2}$ ounces of salt per gallon, and if you continuously blow off $\frac{5}{8}$ of the total feed, what will be the degree of saltness in the boiler?

A. $\frac{5}{8} = 62.5$ per cent.

$62.5 : 100 :: 4.5$: Answer.

$$\frac{4.5 \times 100}{62.5} = 7.2 \text{ ounces per gal. (Ans.)}$$

Q. The blow-off cock on the bottom of a boiler is 13′ below sea level; the water level in the boiler is carried 9′ above the blow-off cock; how much pressure will be needed in the boiler to enable you to blow out water?

A. The water level in the boiler is below the sea level by an amount equal to $13 - 9$, or 4 feet.

4 feet corresponds to a pressure of $.434 \times 4$, or 1.736 pounds.

Therefore a pressure a little greater than this will be needed in order to blow out.

Q. If the feed-water has $4\frac{2}{10}$ ounces of salt per gallon, and if you do not wish to exceed a saltness of $9\frac{1}{2}$ ounces in the boiler, what percentage of the feed-water must be blown off?

A. 9.5 : 4.2 : : 100 : Answer.

$$\frac{100 \times 4.2}{9.5} = 44.2 \text{ per cent. (Ans.)}$$

REQUIREMENTS FOR ENGINEERS IN THE REVENUE MARINE.

The requirements for engineers in the Revenue Marine are about the same as those for chief engineers in the Merchant Marine, as will be seen by comparing the following extract from the general orders of the treasury department with the corresponding paragraphs in the Frye Bill. On this account no questions and answers for candidates have been inserted.

1. No person will be examined for, or commissioned a second assistant engineer in, said service who is not a citizen of the United States.

2. Candidates must not be less than twenty-one nor more than twenty-eight years of age, and must be of vigorous constitution, physically sound and well formed, and not less than five feet three inches in height.

The application for examination must be in the handwriting of the applicant and addressed to the Secretary of the Treasury. It must state the date and place of birth, and the State of which a resident. If the applicant be of foreign birth it must be shown that he is a citizen of the United States.

3. The application must be accompanied with satisfactory evidence of the good moral character

and correct habits of the applicant, and certificates showing his experience either in a machine shop or in charge of a steam engine in a technical institution, or in the engine room of a steamer, as required by paragraph 5.

4. Candidates will be required to pass a satisfactory examination as to their physical qualifications before a board of medical officers to be designated by the Secretary of the Treasury. The physical examination will precede the professional, and should the candidate be found physically disqualified he will be examined no further.

5. To be eligible for examination a candidate must have had not less than eighteen months' experience in a machine shop, or responsible charge of a steam engine for that length of time ; or, if a graduate of a technical institution, he must have had the full four years' course in mechanical engineering ; and in addition to either of the three preceding requirements, he must also have had not less than six months' experience in charge of, or assisting in, the care and management of the steam machinery of a sea-going vessel in actual service.

6. Candidates having been found physically qualified will be examined professionally by a board of engineer officers of the Revenue Cutter Service, in the following subjects, the questions and answers all being written :

(*a*) Grammar, spelling, punctuation, composition, penmanship.

(*b*) Statement of shop and engineering experiences and sea-service.

(*c*) Elementary mathematics, including arithmetic, algebra, geometry, trigonometry, and the use of logarithms.

(*d*) Elementary mechanics and physics, including mechanical powers, friction, laws of falling bodies, force, work, etc.

(*e*) Practical problems connected with steam-engineering, such as calculation of loss by blowing off, gain by use of heaters, amount of condensing water required, safety valve problems, etc.

(*f*) Incrustation and corrosion in marine boilers and problems connected with combustion.

(*g*) Marine boilers, description of various types, with their advantages and disadvantages, repairs to same, practical management of boilers, and discussion of accidents and difficulties, such as foaming, back-draft, etc.

(*h*) Heat, steam, theory of expansion, use of steam.

(*i*) The steam-engine indicator, interpretation from diagrams therefrom, calculation of horse-power and evaporation from diagrams.

(*j*) Marine engines—description of the various types including those used with paddle-wheels, with advantages and disadvantages, special attention being given to multiple-expansion engines, practical questions relative to care and manipulation of engines, overhauling and repairs, alignments, etc.

(*k*) Valves and valve-gears as applied to marine engines, including those used on side-wheel steamers, but with special attention to modern types used with propeller engines.

(*l*) Condensers, pumps, steam gauges.

(*m*) Strength of materials, including simple problems in proportions of marine engines and boilers. Inspection of materials.

(*n*) Screw propellers. Description of common types; definitions and simple problems connected therewith.

7. The professional examination will be competitive, and all candidates who pass the minimum standard will be placed upon an eligible list in the order of proficiency exhibited by them respectively, in the examination. From this list selections will be made in regular order as vacancies occur, until another examination is held.

8. The standard of proficiency has been fixed at 75 per cent., and candidates failing to obtain that average will be rejected. They may, however, if otherwise qualified, take another examination when the next board shall be convened. Failure in the second examination will result in the final rejection of the candidate.

9. No person shall be originally appointed to a higher grade than that of second assistant engineer.

10. Any person producing a false certificate of age, time of service, character, or making a false statement to the Board of Examiners, shall be disqualified for appointment.

11. Any person who subsequent to his examination may become disqualified from moral considerations, will not be recommended for appointment.

12. All correspondence with reference to the provisions of this order should be addressed to the Secretary of the Treasury, Washington, D. C.

ELECTRICAL QUESTIONS.

QUESTIONS FOR DYNAMO TENDERS.

(Based upon low-pressure, direct-current work.)

Q. What are the essential parts of a dynamo?

A. The armature, the field magnet, and commutator and brushes.

Q. What are the functions of these parts?

A. The magnet and armature when moved relatively to each other set up an electric pressure between the ends of the armature coils. Whenever the two ends are connected by a conductor an electric current will flow; the commutator and brushes serve to collect the current and to make the current flow always in the same direction in the external circuit.

Q. What do you mean by the external circuit?

A. That portion of the circuit outside of the dynamo.

Q. What analogy has a dynamo to a pump?

A. The dynamo may be considered as a pump which raises electricity from a low level or pressure to a high level or pressure.

Q. Upon what does the pressure produced by the dynamo depend?

A. Upon the number of turns of wire in the armature coils, upon the strength of the field magnets and upon the speed of revolution.

Q. What would be the effect on a given dynamo of increasing the speed of the driving engine?

A. It would increase the pressure furnished by the dynamo, although not in an exact proportion to the change in speed.

Q. How is an armature constructed practically?

A. The armature consists first of a shaft on which are mounted a large number of thin, circular, iron discs. These discs are held together by bolts and are fastened to the armature shaft by a sort of spider. These discs together form a cylinder the outer surface of which has usually a number of grooves cut in it running parallel to the armature shaft. The coils of the armature, which consist of copper wire insulated with cotton, are wound around the cylindrical core, the wires being laid in the grooves. The grooves are generally lined with a thin insulating material such as paper fiber or even mica, and the wires are painted over with shellac or special armature varnish. Finally, on the outside are wound binding wires so as to hold the armature coils in place.

Q. What is the purpose of the cylindrical iron core in the armature?

A. If the iron core were not used a large part of the magnetism produced by the field magnet would be wasted, as the magnetic lines of force would not pass across the space wherein the armature coils rotate. The iron core keeps these lines of force within the proper space.

Q. What is the object of making the core of thin discs rather than of solid metal?

A. If it were made of solid metal it would become very hot, and this would not only produce a waste of energy, but it would also injure and perhaps entirely destroy the insulation of the armature coils.

Q. Is the magnet of the dynamo a permanent magnet?

A. In early dynamos it was; in modern times it is always an electro-magnet.

Q. What is an electro-magnet?

A. An electro-magnet consists of a piece of iron or soft steel surrounded by a coil of wire carrying an electric current.

Q. How many poles has an electro-magnet?

A. It must have at least two, or it may have any even number of poles, such as 2, 4, 6, 8, etc. In any case half are of one polarity and the other half of the opposite polarity.

Q. How are dynamo machines classified according to the winding of their field magnets?

A. Into three classes: Series, shunt, and compound machines.

Q. What is a series machine?

A. A series machine is a dynamo through whose field-magnet coils flows all the current produced by the machine. This is accomplished by taking a wire from one brush, carrying it the required number of times around the field magnet and then connecting it to the external circuit; the other end of the external circuit is connected to the other brush.

Q. What is a shunt dynamo?

A. One in which only a portion of the total current of the machine passes through the field-magnet coils.

Q. What is a compound dynamo?

A. A dynamo having two windings: one series winding, around which the main current flows; and a shunt winding, through which a fraction of the main current flows.

Q. For what class of work is a shunt machine used?

A. A shunt machine is used when it is desired to maintain a constant pressure at all loads.

Q. Does a shunt machine maintain a constant pressure at all loads?

A. Nearly so; the pressure falls off a little as the load increases.

Q. What system of distribution requires a constant pressure at all loads?

A. The ordinary parallel or multiple system used for the lighting of buildings.

Q. Are shunt machines used in general for this class of work?

A. No; they have been superseded very largely by the compound machine, which gives a closer regulation of pressure.

Q. What is meant by an overcompounded machine?

A. One which automatically raises the pressure a little in proportion as the load increases.

Q. What are the advantages of such a machine over one that would maintain the pressure absolutely constant?

A. Such a machine would make up for a slight fall in the speed of an engine, which takes place as the load increases; it also makes up for a loss in pressure on the circuit wires, which loss is proportional to the load which they carry.

Q. How is overcompounding actually obtained?

A. By increasing the number of turns in the series coil of a compound machine above what would be necessary to give a constant pressure machine.

Q. Can the pressure furnished by a shunt or compound dynamo be varied? and if so, how?

A. Yes; it could, of course, be varied by altering the speed of the engine, but the common method is to insert an adjustable resistance called a "rheostat" in series with the shunt field coils. When the arm of the rheostat is turned one way more resistance is thrown into the shunt circuit, which cuts down the current flowing around the coils. As this diminishes the strength of the field magnet the pressure furnished by the machine is lessened. Moving the rheostat arm in the other direction cuts out resistance and raises the pressure.

Q. How are machines classified with regard to their field magnets?

A. They are classified according to the number of poles into bi-polar, or two-pole machines, and multi-polar, when the number of poles is greater than two.

Q. How does the number of brushes compare with the number of poles?

A. As a rule, there are as many sets of brushes as there are poles.

Q. What are the two principal methods of winding armatures?

A. The ring winding and the drum winding.

Q. Explain what must be done in setting the brushes so as to secure freedom from sparking.

A. In a bi-polar machine the positive and negative brushes must be exactly opposite each other. In the four-pole machine these brushes must be at a distance of 90 degrees from each other. In any case the brushes must fit the surface of the commutator accurately, and the rocker arm which carries them must be turned into the position of least sparking.

Q. What care must be given to a dynamo in order to make it run properly?

A. It must be kept clean and dry. The bearings, of course, need no more nor no less attention than similar bearings in other machinery. The parts which require the most care are the commutator and brushes.

Q. Explain in detail what care must be given to the commutator.

A. The commutator should be kept clean by occasionally wiping it with a hard-cotton cloth, and a very little vaseline should occasionally be put on it so as to diminish the friction between the commutator and brushes. Oil should never be put on it. The commutator will in course of time become roughened, and therefore it should be occasionally smoothed by holding a piece of very fine sandpaper against it while the machine is turning. If the commutator gets out of true it must be turned down.

Q. How is the commutator turned down in the case of a small-sized armature?

A. The armature is taken out from its bearings and mounted in a lathe, and the commutator is turned off just like any other piece of metal.

Q. Is there any particular necessity for observing care in turning down the commutator?

A. Yes; the tool should take only a very fine cut, and after the job is finished the commutator should be very carefully examined to see that no two commutator segments have been accidentally connected by a little piece of copper that has been partially torn off from one segment by the cutting tool and pushed over so as to touch the next segment.

Q. Suppose that there had been a connection established between two commutator segments and that this had not been discovered; the armature is then put back in place and the machine started up, what would be the effect?

A. The coil whose ends are connected to these two commutators would become very much heated, and unless the machine were stopped the whole armature would become badly damaged. There would also probably be considerable sparking at the brushes.

Q. After the brushes are once properly fitted so that the machine runs without sparking, what care must be given to them?

A. They must be occasionally cleaned, and if any sparking occurs they should be immediately adjusted so as to stop it. If the brushes are of copper they should be raised from the commutator whenever the machine is stopped, so that they may not be injured in case the machine were for any reason turned backward.

Q. What would be the effect of allowing the dynamo to become wet?

A. The insulation of the armature and field coils would be injured if not entirely destroyed. It would be, as we say, grounded—that is, put in electrical connection with the frame of the machine.

Q. What do you mean by the term "badly grounded"?

A. The armature, for example, would be badly grounded if the insulation resistance between the coils and the iron core became very low.

Q. How many ohms insulation resistance between the armature or field coils and the frame is it usual to demand in a good dynamo?

A. An insulation resistance of at least 1,000,000 ohms.

Q. How could you determine whether or not the machine were grounded?

A. I should take a magneto bell and connect one terminal to the frame of the machine, being careful to have the connection on a metal surface which had been made clean and bright. The other terminal of the magneto I would connect to one of the brushes. It is understood that the machine is not to be operated while the test is being made. I would then turn the handle of the magneto, and if the bell sounded I should know that there was a bad ground somewhere in the machine. To locate it I would raise the brushes from the commutator and turn the magneto again. If it rings this shows that there is a ground either in the brush holders or in the field circuit. I would then disconnect the field circuit from the brush holders and test each separately, and after having found, for instance, that the ground was in the field coils I would disconnect them so as to find in which particular coil the trouble existed. I would afterward test the armature to find if there were any ground in it.

Q. In case you found that there was a ground in the armature, what would you do?

A. I would examine it carefully, especially at the commutator end, to see if it were caused by a collection of metal dust and oil or by anything else which I could remedy. If the cause of the trouble could not be found it would be necessary to take the armature out and send it to some shop where they make a specialty of rewinding armatures.

Q. Suppose that you were at a distance from such a shop, would you attempt to repair the trouble yourself?

A. If it were a small ring-wound armature I might do so, but certainly would not attempt it in any other case.

Q. Suppose that a ground were found to exist in one of the field coils, what would you do?

A. I should not hesitate to attempt to repair that. I would take out the spool on which the coil is mounted and would put it in a lathe and carefully unwind the coil, winding the wire up at the same time on some sort of drum or reel so as not to kink or injure it in any way. I would occasionally test with a magneto bell, connecting one terminal to the metal of the spool and the other terminal to the wire, and would keep on unwinding until the coil showed free from a ground; then I would repair the place where the trouble was found by putting in some new insulation or new wire as might be needed, and would carefully wind back the wire in exactly the same way that it had been wound by the manufacturer. I would then replace the spool in the machine, testing again for grounds, and would reconnect the machine, and after making a final test for grounds would start it up.

Q. What is a direct connected machine?

A. A direct connected dynamo is one which is driven by an engine without the use of the belt; either the armature shaft is connected to the engine shaft by means of the flexible coupling or more commonly the engine shaft is made extra long with an out-board bearing, and the armature is mounted on this shaft, the field magnets being attached to the extended bedplate of the engine.

Q. What advantages and disadvantages can you think of in connection with direct connected dynamos?

A. Their advantages are: economy of space, quietness in operation, and increased efficiency, since losses in belt transmissions are done away with. Such generators are, however, more costly, since they must run at a comparatively low speed, they being subject in this respect to the limitations of the engine. A belted machine may have its frame thoroughly insulated from earth while the direct connected machine, if the armature is mounted on the engine shaft, cannot enjoy this advantage.

Q. Does a single ground on the circuit or in the machine do any harm?

A. No; it requires two grounds. Nevertheless, in case a ground exists it should be promptly located and the trouble remedied.

Q. In case of two grounds existing, what things may occur?

A. The fuse or fuses may blow ; one or more of the conductors may become overheated or a spark may pass across the grounded spot, and either of these last two effects may set fire to any combustible matter in the vicinity.

Q. Explain the general method by which electrical energy is distributed for ordinary house lighting.

A. The distribution is very similar to a water system in which water is pumped from a tank at a low level to an elevated tank and then led from this tank through pipes to the various points where it is to be used, and after having been used is led back through another set of pipes to the low level tank from which the water is again pumped up to be used again. The dynamo corresponds to the pump ; the copper wires correspond to the distribution pipes and the two bus bars on the switchboard correspond to the two tanks. The switches correspond to the valves, the ammeters correspond to water meters, and the voltmeters correspond to pressure gauges.

Q. What is the high-pressure system of conductors called in electrical distribution ?

A. The positive, or plus (+).

Q. What is the low-pressure set of conductors called ?

A. The negative, or minus (—).

Q. Explain how, practically, a generator is connected to a switchboard, describing the materials used and the manner in which they are installed.

A. There are several methods of construction. The conductors may be carried overhead ascending vertically from the machine terminals to the ceiling of the dynamo room and then across the ceiling and vertically downward to the fuse terminals of the machine switches on the switchboard. In this class of construction the conductors may be bare copper rods or may be wire insulated with fire- and weather-proof or rubber insulation. The conductors in either case are attached to porcelain insulators. If bare copper rods be used, that portion of their length which is near the generator should be covered with insulating tape.

Another and more common method is to carry the conductors under the floor of the dynamo room, placing them in iron pipe or conduit ; in this case the conductors should be insulated with rubber, or a lead-covered cable may be used.

A third method is to carry the conductors under the floor in a brick or concrete duct covered with iron plate ; in such cases the conductors may be mounted on porcelain, but as this necessitates a very large duct it is better to use for conductors a lead-covered cable.

Q. Trace the connections from the generator to the bus bars, stating through what pieces of apparatus the current would pass.

A. Starting from the positive brush the conductor runs from the brush to a fuse terminal on the machine switch; the current after passing through this fuse passes through the positive blade of the machine switch and then through the ammeter (or ammeter shunt) and through a connecting strip to the positive bus bar. From the negative bus bar the current passes through a copper strip to the machine switch, through the blade of the switch and the corresponding fuse, and then through a conductor which extends from the fuse terminal to the negative brush.

Q. What is the object of a fuse, and of what is it made?

A. A fuse generally consists of a piece of composition metal,—usually some alloy of lead which will melt at a fairly low temperature,—soldered to copper terminals, these terminals being of such shape that they may be conveniently clamped under lugs provided to receive them. The fuse is intended to melt whenever a current exceeding a certain strength passes through it. It therefore serves to protect either the circuit conductors or the machine from overheating due to the passage of too great a current.

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Q. What are used instead of fuses, and what are their advantages?

A. Circuit breakers. They are more certain in their action, especially with large currents. The large fuses which must be used for large currents are very unreliable, and fuses, for example, which are intended to melt with a current of, say, 500 ampères may be melted by a current below that value or may not blow until the current has risen to perhaps 1000 ampères.

Q. What is the general principle on which circuit breakers are constructed?

A. A circuit breaker is essentially a switch which automatically opens when the current exceeds a certain amount. It is closed against the pressure of the spring, which pressure will throw it open if the switch is not held in by a sort of trigger or catch. This trigger is controlled by a coil through which the current passes. If the current becomes greater than a certain value the coil sucks up an iron rod attached to the trigger and releases it; the compressed spring then being free to act upon the switch interrupts the circuit.

Q. What circuit breakers are usually provided by the switchboard?

A. One for each generator. In many installations each feeder circuit is provided with a circuit breaker, no fuses at all being used on the board.

Q. What is the difference between a double-pole breaker and single-pole circuit breaker?

A. The same difference as exists between a double-pole switch and a single-pole switch. The double-pole switch when open interrupts both the positive and negative sides of the circuit; the single-pole interrupts only one side.

Q. Which kind of circuit breaker is the better to use, a double or single pole?

A. The double pole.

Q. When single-pole circuit breakers are used with compound machines, in which of the connections between the dynamo and switchboard must the circuit breaker be placed?

A. In the side opposite that in which the series coil is connected.

Q. When two or more compound machines are run together, how many connections run from the dynamo to the switchboard from each machine?

A. There are three large conductors—namely, the positive, the negative, and the equalizer.

Q. What is the purpose of the equalizer connection, and what does it connect?

A. The equalizing connection runs from the inner end of the series field coil to the corresponding point on the other machine. It passes from machine No. 1 to a switch on the switchboard, then back to machine No. 2. If there are more than two machines the equalizing connection runs from the series coil to the switch on the board and from the switch to an equalizer bus bar. The purpose of the equalizing connection is to enable the machines to be operated together satisfactorily. If it were not used the machines would not tend to divide up the total load properly. By adjusting the rheostats the machines can be made to take their proper share of the load without the equalizing connection; but if the speed of one engine diminished slightly the machine corresponding would take a much less portion of the load, and this action would be aggravated so that shortly one machine would be carrying all the load and perhaps driving the other as a motor. The equalizing connection prevents this action.

Q. What small connections are there between the generators and the switchboard?

A. The field connections which may be run in either of two ways. First, the outer end of the field coil on the generator is connected to one of the rheostats by a wire and a return wire connects the other terminal of the rheostat to a brush of the proper polarity; in the second method the return wire is omitted, a connection being made between the rheostat terminal and the bus bar of the proper polarity.

Q. What are the principal devices to be found on a switchboard, and what is the purpose of each?

A. (1) An ammeter in the circuit of each generator for the purpose of measuring the current passing through each machine. (2) One or more voltmeters. If only one voltmeter be used it is provided with a many point switch by which it may at will be connected to the bus bar or to the terminals of any generator. If there be two voltmeters, one is connected permanently to the bus bars and the other is provided with a switch. (3) A rheostat for each generator, by which the pressure furnished by each machine may be varied. (4) Circuit breakers or fuses in the machine circuits and in the feeder circuits, whose function is to interrupt any particular circuit through which an excessive current may for any reason flow. (5) Switches for disconnecting the generators from the bus bars. (6) Switches for disconnecting the distribution circuits from the bus bars. (7) A ground detector whose purpose is to show if any part of the circuit becomes connected to the earth.

Q. Explain the arrangement and action of a two-light ground detector when used on a 110-volt circuit.

A. The two-light ground detector consists of two 110-volt lamps connected in series across the bus bars. A point on the circuit between the two lamps is connected to earth by attaching it to a convenient water pipe. The operation is as follows: So long as the insulation of the system is unimpaired the two lights will burn dimly and equally so, since they have only 55 volts pressure between their terminals. If, however, there is a bad ground on one side of the circuit, say, the positive, the lamp connected to the positive side will become very much more dim, since there is now an auxiliary circuit across its terminals through the earth. The other lamp will burn brightly, since the pressure between its terminals is very much greater than before.

Q. Suppose that one of the ground detector lamps burns brightly, how would you proceed, practically, to find the ground?

A. I would open the circuit switches one by one and watch the ground detector to see if the opening of any one of them made the lamps again both burn equally dim. If this were the case I should know that the ground were located on that part of the circuit controlled by this switch. I would then go out to the first distribution board on that circuit with a portable ground detector, if I had one, and connect it up at that point. I would then open the switches or fuses one by one until I found which branch contained the ground. I would then leave that branch disconnected and with a magneto bell would test different parts of that branch circuit, splitting it up into sections at some convenient outlet or switch. In this manner the ground would be located within quite close limits. If I found that the ground were on a short piece of the circuit on which a fixture were connected I would disconnect the fixture, and test with the bell both the fixture and the wiring. If the wiring showed the ground I would run in a new piece of wire to take its place.

Q. When three-pole switches are used for machine switches, what is connected to each blade?

A. The positive side of the generator to one of the outside blades, the equalizer to the middle blade, and the negative side of the machine to the other outside blade.

Q. May shunt machines be run together in multiple?

A. Yes.

Q. Do shunt machines when run in multiple need an equalizer?

A. No.

Q. Explain how you would proceed if you had one machine in operation and you desired to start up a second in multiple with it to take care of an increase in load, both machines being compound.

A. I would start up engine No. 2 and adjust its rheostat until the voltmeter showed its pressure to be about $\frac{1}{2}$ volt greater than that of machine No. 1. If each machine had a three-pole switch I would close the switch of No. 2, adjusting the rheostat handles until the ammeters read alike (if the machines are of the same size) and the bus bars are at the desired voltage. If the machines have a two-pole switch with a separate switch for the equalizer, I would close the equalizer switch first and then close the double-pole machine switch, afterward adjusting the rheostats.

Q. Sometimes you will see a switch in the field circuit. Should this ever be opened when that machine is in operation?

A. Never.

Q. What would be the effect of opening the switch?

A. It would produce a strong spark at the switch, and would be liable to seriously injure the insulation of the field coils of the machine, because the opening of the circuit produces for a moment a very high electric pressure that is liable to pierce the insulation.

Q. Suppose two machines designed for 400 ampères each are operating in multiple on a load of 600 ampères, and the fuses or circuit breaker of one of the machines opens the circuit, what effect would you notice?

A. There would probably be great sparking or flashing at the commutator of the other machine, because it would be very much overloaded.

Q. What would you do in this case?

A. Quickly open the circuit switches one by one; and if this did not remedy the trouble, open the machine switch; and if this did not stop it, turn the rheostat handle so as to lower the voltage to the smallest possible amount and shut down the engine. If the trouble were due to nothing more than overloading, it would be remedied by the opening of a sufficient number of circuit switches.

Q. What are some of the troubles to which rheostats are liable?

A. Some of the coils may be burned out or grounded, or some of the contacts may become defective.

Q. In case a single machine is running and a coil of its rheostat should burn out, what would be the effect?

A. The lamps on the circuit would all go out, since the opening of the field circuit would destroy the magnetism of the machine and it would furnish no pressure.

Q. How would you remedy the difficulty temporarily?

A. By connecting wire across the terminals of the burned-out coil.

Q. Suppose that two machines were running in multiple at the time the rheostat coil burned out, what would happen?

A. One of the machines would become overloaded, producing serious sparking or flashing.

Q. Suppose that one coil of the rheostat became grounded, how would you remedy it?

A. By disconnecting that coil from the others and putting in a temporary connection of wire to take its place.

Q. What are some of the methods of constructing rheostats for dynamos?

A. The older method was to make up coils of wire insulated on porcelain or other suitable material and mounted in an iron framework or box, the terminals of the coils being connected to suitable brass plates over which the rheostat arm played. The more modern method is to imbed the wire coils in an insulating enamel, the wires being wound in a flat coil instead of a spiral, so that they may lie very close to the iron framework; this construction gives much greater compactness.

Q. How is the Weston switchboard voltmeter constructed?

A. It consists of a permanent magnet of horseshoe form between the poles on which is pivoted a small coil of very fine wire connected to proper terminals. Whenever a current passes through a wire the coil tends to turn in a certain direction against the action of springs which tend to hold it in place. The stronger the current the greater the deflection of the coil. Attached to the coil is a light needle which plays over a graduated scale.

Q. How does the ammeter differ from this?

A. The ammeter is constructed in the same way, but only a very small fraction of the current to be measured passes through the coil. The greater part of the current passes through the shunt of the instrument, this shunt being placed in one of the leads coming from the machine. The terminals on the shunt are connected to the terminals on the ammeter through a pair of flexible leads about ten feet long.

Q. Would it do any harm to cut off a part of these leads?

A. Yes; it would totally destroy the accuracy of the instrument. Each instrument requires a special pair of leads of the proper resistance.

Q. How could you roughly test the accuracy of your ammeters?

A. By operating first one machine on a certain number of lamps at 110 volts exactly; then throw off that machine and operate the same number of lamps with the other machine at the same pressure. If the readings of the ammeter were practically the same in the two cases it is fair to assume that they are reasonably correct. The ammeters can also be tested against the circuit breakers. If the circuit breaker always goes off at the same reading of the ammeter it may be assumed that the ammeter has not lost its accuracy.

Q. How can the voltmeter be tested by comparison with some other voltmeter supposed to be correct?

A. The two voltmeters are connected up in multiple across the bus bars.

Q. Would you attempt to repair an ammeter or voltmeter that was out of order?

A. On no account.

Q. How does a direct current motor differ from a dynamo as regards construction?

A. Only in details of design. Practically, any direct current dynamo will operate satisfactorily as a motor if current be supplied to it.

Q. What would you do in case you desired to reverse the direction in which a motor runs?

A. I would change the connections so as to reverse the direction of current through either the field or the armature, and if necessary to prevent sparking would shift the rocker arm that carries the brushes.

Q. For what class of work are series motors used?

A. Series motors are used in those cases where it is necessary to start with full load and where automatic regulation for constant speed is not necessary, as in hoists, cranes, street railways, etc.

Q. When are shunt motors used?

A. In those cases where automatic regulation for constant speed is desired.

Q. Are compound motors ever used?

A. Yes; in cases where closer speed regulation than that given by shunt motors is desired.

Q. How is the change of speed accomplished in the case of the series motor supplied from a constant pressure circuit?

A. There are two methods commonly used. One is to change the pressure supplied to the motor by putting in series with it a rheostat in which more or less pressure is used up according to the position of the rheostat handle. Lowering the pressure supplied to the motor lowers its speed, and *vice versâ;* the other is to change the strength of the field of the motor. The field coils are wound in sections, and the ends of the sections are brought out to a species of commutator called the controller. In one position of the controller handle the sections are connected in series, which cuts down the current strength and makes the field magnet comparatively weak. In the next position three of the sections, for example, will be in series, and three others in series, and the two sets of three will be connected in multiple. This arrangement diminishes the resistance of the circuit and lets more current through; another position puts more sections in multiple and fewer in series, and so on until the final step puts all the sections in multiple, giving the lowest possible resistance and the strongest possible field. Frequently, the combination of the two methods is used, the resistance being employed on the first positions of the rheostat handle in order to cut down the excessive flow of current on starting.

Q. In what way are shunt motors regulated for changes in speed when supplied from constant pressure circuits?

A. By putting resistance coils in series with the armature and cutting out more or less of them according as a higher or lower speed is desired, or by putting a rheostat in series with the field circuit and varying the current around the field coils by adjusting the rheostat handle.

Q. How are compound motors regulated for changes in speed?

A. Generally like shunt motors, although in some cases the series coils are wound in sections thrown in series and multiple by the controller.

Q. In starting up a shunt or compound motor, what precaution is necessary and why?

A. Considerable resistance must be put in series with the armature. If this were not done the very low resistance of the armature would permit the flow of an enormous current which would blow fuses or overheat the armature coils and cause excessive sparking at the brushes. As the machine speeds up this resistance is cut out. The whole arrangement is automatically arranged for by the starting box that is supplied with each motor.

Q. What other protective devices are required with shunt motors?

A. Motors must be protected from the danger of overload which by slowing down the motor diminishes its back electro-motive force. This would allow an excessive current to flow, which if long continued would burn out the armature coils. Formerly this protection was provided by fuses. At the present time a circuit breaker mounted on the starting box is almost universally employed. Another thing that must be guarded against is the accidental temporary interruption of the supply circuit (which would of course stop the motor) and its being subsequently closed again. If this happened it would throw full voltage on the motor armature, and this would result in an excessive flow of current. To guard against this difficulty the starting box is arranged so that whenever the pressure of the circuit is diminished below a certain amount or is zero in case of actual interruption of the circuit, the rheostat arm is pulled back into the position which throws a resistance in series with the armature.

Q. What is a motor generator?

A. A combination of motor and generator on the same shaft.

Q. How are dynamos and motors rated?

A. Dynamos are rated, as regards their capacity, in kilo watts, and motors are rated in horse-power.

Q. What is the relation between the kilo watt and the horse-power?

A. One horse-power is practically equivalent to $\frac{3}{4}$ kilo watt.

Q. What is the arrangement of the Edison three-wire system?

A. See "Roper's Catechism," page 311.

Q. Can a system of house wiring installed on the Edison three-wire system be operated from one machine, and if so, how?

A. Yes; the two outside feeders must be connected together so as to be of the same polarity and joined to one of the brushes or bus bars. The neutral feeder must be connected to the other brush or bus bar.

Q. Is this arrangement ever employed in practice?

A. Often; it is arranged so that the change of connections is made by a double-throw switch. In one position of the switch the house circuit is thrown on to the Edison mains; in the other position of the switch the circuit is thrown on to the house generator.

Q. What is the commercial efficiency of a dynamo?

A. It is the ratio between the amount of electric power furnished by the dynamo and the amount of mechanical power delivered to the dynamo.

Q. How can the efficiency of a dynamo be measured?

A. By indicating the engine when the dynamo is full loaded and noting the reading of the ammeter and voltmeter, then indicating the engine when the dynamo is running idle with no current flowing through the fields. The difference between the horse-power of the two indicator diagrams is very closely the amount of mechanical power supplied to the dynamo. The product of the volts and ampères divided by 746 gives the power developed by the dynamo; the quotient of the latter by the former is the commercial efficiency of the dynamo.

QUESTIONS FOR ELECTRICIANS OR WIREMEN.

Q. What are the principal systems of distribution for electric lighting?

A. The series system and the parallel system.

Q. What is the difference between the two systems?

A. In the series system the lamps are connected in tandem, the entire current flowing successively through each lamp. In the multiple system the current from the dynamo is divided, a part flowing through each lamp. After passing through the lamps the separate currents unite and flow back to the dynamo.

Q. On which of these systems are motors generally operated?

A. On the parallel system.

Q. To what class of work is the series system practically confined?

A. To outside arc lighting.

Q. What is the vital necessity on a series system to make the lighting successful?

A. The series system must be a constant current system; that is to say, cutting out or in more or less of the lamps must not alter the value of the current.

Q. What is necessary on the multiple or parallel system?

A. This system is necessarily a constant potential or constant pressure system—that is, turning on or off lamps must not materially alter the pressure on any other lamps.

Q. What is the Edison three-wire system?

A. The Edison three-wire system is a peculiar combination of series and multiple systems. Two lamps are placed in series with each other and the sets of two are in multiple with each other. A conductor, called the neutral, connects the point of junction of the lamps which are placed in series with each other and runs to the point of junction of the two generators (in series with each other) which supply the system.

Q. What is the advantage of the Edison system?

A. The Edison system secures economy in the size of wire, from the fact that it permits the distribution at a higher pressure without any serious disadvantages; for example, the distribution on the feeders and mains is essentially at 220 volts, while the pressure on the branch circuits and the lamps is only 110 volts.

Q. Could not the same economy be obtained by using a simple multiple system with 220-volt lamps?

A. Yes; but it is difficult to make good 220-volt lamps and 110-volt lamps are superior to them. Moreover, the lower pressure lamp is more desirable from the standpoint of safety, since there will be less liability to leakage from the circuit when the lower pressure is used. A shock from the 110 volts is scarcely noticeable or at any rate not disagreeable, while the shock from 220 volts is quite severe.

Q. What determines the necessary size of wire in any particular case?

A. There are two requirements which must be met: *First*, the wire must be large enough so that the current that will flow through it will not heat it beyond a certain amount; this requirement has been definitely laid down by the Fire Underwriters, who provide tables stating the allowable current for various sizes of wire. *Second*, the size of wire is determined by the amount of energy which we are willing to lose on it. This loss of energy depends on the current that will flow and the resistance of the conductor.

Q. What loss of pressure is allowable on conductors?

A. There is no definite rule for this. In buildings, the total loss of pressure from the generator to the most distant lamps seldom exceeds 5 per cent. and with the ordinary system of multiple wiring is rarely more than 3 per cent. of the voltage of the lamps. A part of the loss is on the feeders, another part on the mains, and the rest on the branches and in the switches, fuses, etc.

Q. Explain how you would calculate the size of wire to be used in the following case: Ten 16 c. p. lamps whose voltage is 110 are to be supplied by current from a dynamo 200 feet away. The loss permissible is 1 per cent.

A. Since the allowable loss is 1 per cent. the volts lost will be 1.1. The current for ten lamps will be practically 5 ampères. The total length of wire will be 2 × 200, or 400 feet. By Ohm's law $C = \frac{E}{R}$ or $R = \frac{E}{C}$. Therefore $R = \frac{1.1}{5}$, or .22, hence the wire must be of such size that 400 feet of it has a resistance of not over .22 ohm. 1000 feet of this size would have a resistance equal to .22 × 1000 divided by 400, or .275. Looking in the wire tables under the column headed ohms per 1000 feet, it will be found that a No. 4 wire fulfils the requirement. Finally, looking in the table of safe carrying capacities given by the National Board of Fire Underwriters it is found that a No. 4 wire will more than carry the current with safety.

Q. What varieties of electric wiring are there?

A. Open work, such as porcelain work and moulding work; and concealed, where the wires are carried on porcelains or in conduits.

Q. What kind of conduits are used at the present day?

A. For the great bulk of the work iron or steel conduits, of which there are two varieties: one in which the tube, which is practically a gas-pipe, is lined with some insulating compound; the other, where the tube is covered inside and out by a hard enamel.

Q. What is circular loom conduit, and in what cases can it be used and where must it not be used?

A. Circular loom tube is a semi-flexible conduit made of paper and covered with cotton, which is used in buildings of wooden construction, particularly in cases where it is desired to install electric work in an old building. The circular loom is used to cover the wires run down partitions, since it may be *fished* in without injuring the finished work in the house. It is absolutely useless in those cases where it is liable to be subjected to moisture or is in contact with cement; it must therefore be regarded as a makeshift, to be used only in those cases where iron conduit cannot on account of its stiffness be installed or where the work could not be done on porcelain without destroying costly finished surfaces.

Q. Is there any difference as to the number of wires carried in a C. L. tube or in an iron conduit?

A. Yes; only one wire is carried in C. L. tube; in iron conduit two wires are carried in the two-wire system and three in the three-wire system, except occasionally in case the feeders are so large that it is not possible to draw more than one wire in the tube.

Q. What is the best way to cut off iron conduit, and why?

A. By means of a hack-saw. This method gives a smoother cut and leaves less ragged edges, and does not injure the lining or the enamel as much as the use of ordinary pipe cutters.

Q. After cutting off a piece of pipe, what should be done to the ends?

A. They should be smoothed with a reamer or file.

Q. In making joints in conduits, how should the joints be treated?

A. The pipes should be screwed into the couplings so that they butt against each other, the threads being previously treated with white lead so as to make a water-tight joint.

Q. What are the principal troubles to be avoided in doing conduit work?

A. Too many bends, joints that are not butted together properly and are not water-tight, and rough edges at the joints and at the outlets that will injure the insulation of the wires.

Q. How are conduit tubes fastened into outlet or switchboxes?

A. There are several methods: One is to tap the outlet box with a thread and screw the conduit into this; another is to put a lock-nut on the pipe outside of the box and another lock-nut inside; a third is to put a coupling outside and a special insulated nut inside the box, which nut screws into the coupling.

Q. What are the disadvantages of the first method?

A. It is very difficult to get the switch or outlet box to stand plumb; especially when, as in the case of gang switches, several pipes enter and leave the box.

Q. What is the general arrangement at a sub-switchboard for bringing in the tubes and wires conveniently?

A. The switchboard proper is surrounded by an outer wooden or iron box the walls of which are about 3 inches or 4 inches distant from the inner wall. The latter is generally made of thin slate or marble. The conduit tubes are brought through the outer box and stop there. The wires continue through holes in the inner slate walls and are attached to the proper terminals. The space between the inner and outer walls is covered by the trim of the door. By this arrangement the rough box can be put in before the conduit work is done and the switchboard proper inserted at a later date when the building is nearing completion and the door and trim finally put on just in time to be finished by the painters.

Q. Why are ends of conduit tubes plugged up as soon as they are installed?

A. For two reasons: one to prevent any small objects from getting into the tubes and stopping them up, the other to prevent the condensation of moisture in the tubes, which would injure the insulation of the system.

Q. What are the commercial sizes of conduit at the present time?

A. Conduits are sized according to their nominal internal diameter, the sizes being $\frac{7}{16}''$, $\frac{1}{2}''$, $\frac{7}{10}''$, $\frac{9}{10}''$, $1\frac{1}{4}''$, $1\frac{4}{10}''$, $1\frac{8}{10}''$, $2\frac{1}{4}''$, and $2\frac{3}{4}''$.

Q. How many bends would you allow in a run of conduit?

A. That would depend somewhat on the length of run; in any case I would not allow more than four.

Q. Explain how wires are put into a conduit system.

A. A springy steel wire about $\frac{3}{16}$ of an inch wide and $\frac{1}{16}$ of an inch thick, having a length usually of 100 feet, is pushed into a length of conduit from one of the outlets. A man at the outlet on the other end pulls this wire through and with it a pulling cord or wire. The two wires to be drawn are then attached to the cord or wire and are gradually worked in by the pulling on one end assisted by a pushing and twisting motion on the other end. The friction of the wire against the walls of the conduit is diminished by blowing in powdered soapstone before the wires are drawn in.

Q. What kinds of insulation are used on wires, and for what class of work are these used?

A. The kind of insulation used depends upon the pressure to be used on the system. For electric bell and other signal work, where only a few cells are used, the pressure not exceeding 10 volts, a comparatively low insulation is sufficient. In such cases a wire is covered with two or more layers of cotton impregnated in paraffin. For outside wiring the conductors are covered with two or three layers of braided cotton, impregnated with some bituminous insulating compound. These wires are called weather-proof wires. For inside wiring on porcelain an insulation called fire- and water-proof has been largely used; the wire is covered with a cotton braid impregnated with white lead, and afterward another covering of cotton braid is put on and slicked over with the weather-proof insulation. The practice now is almost universally to use an insulation made up of a mixture of rubber and other insulating materials, usually of a bituminous nature. The higher the pressure to be used, the greater the percentage of rubber that should be employed.

Q. With a run of 100 feet of $\frac{7}{10}''$ conduit having three bends, how large size of wire could you draw in, there being two wires to the tube?

A. About a No. 8, B. & S.

Q. How can you tell whether or not the conductors in a conduit tube are all right?

A. Roughly by means of the magneto bell. I would connect one terminal of the bell to the tube, filing a bright spot for making the connection, and with the other terminal of the magneto would touch first one of the conductors and then the other; if the insulation is very bad the bell will ring. If not, the bell will make no noise. After making this test I would connect one terminal to the other wire and test for short circuit. If the bell were silent on both of these tests I should assume that the wires were in good condition.

Q. Magneto bells are sold as 10,000 ohms, 15,000 ohms, 25,000 ohms, etc., up to 50,000 ohms. What do these terms mean, and which one would you consider best for testing?

A. A 50,000 ohm bell is one which is supposed to ring through a resistance connected across its terminals as great as 50,000 ohms. A

10,000 ohm bell is supposed to ring through a resistance of 10,000 ohms. I would, of course, prefer the 50,000 ohm bell for testing.

Q. What other method of testing the insulating resistance is more accurate?

A. The test with a voltmeter.

Q. Why are two wires carried in the iron tubes?

A. Because it is safer and because if alternating currents are used on the circuit there would be otherwise an excessive loss of pressure.

Q. What is a distribution board, and by what other names is it called?

A. A distribution board is a small switchboard where the current from a main feeder is distributed to supply smaller feeders or branch circuits. It contains fuse blocks and often switches. Other names are sub-switchboard, panel board, tablet board, cut-out box, and center of distribution.

Q. What is a fuse, and why and where is it used?

A. A fuse consists of a piece of metal, usually some alloy of lead which will melt at a fairly low temperature, soldered to copper terminals. It is intended to melt whenever the current passing through it exceeds the safe carrying capacity of the wire which the fuse is designed to protect. Fuses are placed at all points of a circuit where there is a change made in the size of the wires.

Q. What is a closed arc lamp, and what are its advantages over the open arc?

A. The closed arc lamp is one in which the small inner globe surrounds the arc, preventing, to a great extent, air from coming into contact with the arc. The principal advantages of the closed arc lamp are that the consumption of the carbons is very much diminished and the light is steadier.

Q. At what rate do carbons burn in the two types of lamp?

A. Carbons last about seven hours in the open arc lamp and about one hundred hours in the closed arc lamp.

Q. When a single lamp is used on a constant pressure circuit, what is the general arrangement of the mechanism?

A. The current which comes from the line to the positive lamp terminal passes through a coarse wire coil and then through a chain or brush contact to the upper carbon. After passing through the upper carbon across the arc and through the lower carbon it flows through a wire resistance to the other terminal of the lamp and thence to the line. This wire resistance is arranged so that it can be readily varied.

Q. Explain the operation of the lamp.

A. When the current passes through the coil it raises an iron armature or core to a certain height depending upon the strength of the current. Attached to this armature is a clutch device which raises the upper carbon and "strikes" the arc. The lamp burns gradually, consuming the carbons and lengthening the arc. As the arc lengthens its resistance increases and the current becomes less which allows the armature to drop down slightly. The clutch trips against a stop which lets the upper carbon rod slide through a little, thus shortening the arc until the current has increased enough to lift the clutch off from the tripping stop. The feeding of the lamp then ceases and the lamp continues to burn until the arc again becomes too long, when the operation is repeated.

Q. What would you understand by a 2000 c. p. lamp?

A. The meaning of this expression is indefinite. With open arc lamps I should understand a lamp which along the direction in which it gives the greatest amount of light (about 45 degrees from the horizontal) produces an intensity of illumination equal to that of 2000 candles.

Q. How much current passes through such a lamp, and what is the approximate pressure between its terminals and the amount of power used in the lamp?

A. The current is about 10 ampères; the pressure, about 45 volts (not including that which is lost in the wire resistance); and the power therefore is about 450 watts.

Q. What would you understand by a 2000 c. p. closed arc lamp?

A. One that uses about 450 watts power.

Q. What current is used in a nominal 2000 c. p. closed arc lamp?

A. When burning steadily, about 5 ampères. When the lamp first starts up it may be as high as 9 ampères.

Q. What voltage exists across the arc of the closed arc lamp?

A. About 80 or 90 volts.

Q. Why is a wire resistance placed in series with the arc for lamps used on constant pressure circuits?

A. For two reasons: *First*, a certain amount of resistance is necessary to steady the arc; *second*, the remainder of the resistance is used to cut down the pressure from 110 volts to about 50 volts.

Q. Could not two of these lamps be connected up in series across 110 volts circuit and so obviate wasting a large amount of energy in the wire resistance?

A. The construction of the lamps would have to be modified; an auxiliary fine wire coil connected across the arc is introduced and placed so that it controls the armature operating the clutch device. As the arc lengthens the pressure between the two carbons increases, and this sends more current around the fine wire coil which lowers the armature and causes the clutch to feed.

Q. Are the closed arc lamps ever connected two in series?

A. Yes; across a voltage of 220 or more.

Q. In connecting up arc lamps, does it make any difference which terminal of the lamp is connected to the positive side of the circuit?

A. Yes; the upper carbon must be connected to the positive side of the circuit, else the greater part of the light will be thrown upward to the ceiling instead of downward, as it should be.

Q. How can you tell whether the connection has been properly made?

A. While the lamp is burning look at the arc through a smoked glass; in the case of open arc lamps, the upper carbon should have a little crater at its lower end, while the lower carbon should burn slightly pointed. With closed arc lamps the difference in appearance in the two carbons is very much less, though in either case the upper carbon will be the brighter. If a Weston voltmeter is at hand the polarity can be tested by means of it.

Q. What is the difference between a single-stroke bell and a vibrating bell?

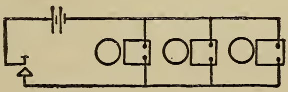
A. A single-stroke bell is one which makes only one stroke for each time that circuit is closed; a vibrating bell is one whose hammer continues to vibrate as long as the circuit is closed. A vibrating bell may be changed into a single-stroke bell by short-circuiting the make and break mounted on the armature.

Q. Suppose that you had several bells that you desired to have vibrate simultaneously from one push-button, how could you arrange them?

A. There are two ways: *First*, the bells could be connected in multiple; *second*, all but one of the bells could be changed to single stroke, that one being left vibrating; then the whole number could be connected in series with each other and with the battery and push-button.

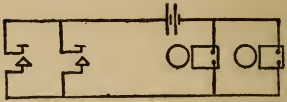
Q. Show by diagram how you could connect three bells to ring by a single push-button.

A.



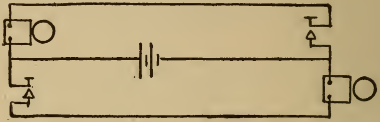
Q. Draw the connections for two bells to be rung by either of two push-buttons.

A.



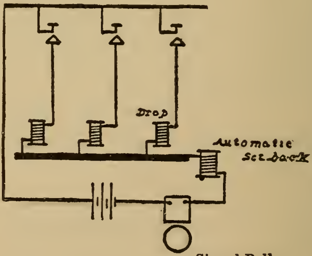
Q. Draw the connections for a return call between two points.

A.



Q. Draw the connections for an annunciator system.

A.



Q. What is an automatic set-back, and how is it arranged?

A. An automatic set-back is a device by which an annunciator shows only the last call which has been made. This is accomplished by an auxiliary electro-magnet placed in the annunciator so connected that current flows through it whenever any push-button is pressed. Attached to its armature is the rod which resets the needles.

Q. Draw the connections for a return call annunciator system.

A. See "Roper's Handy-Book," page 762.

Q. Should there be an automatic set-back on an elevator annunciator?

A. No.

Q. How does a burglar-alarm system differ from an ordinary annunciator system?

A. The push-buttons that are placed in doors or window casings are of a different pattern, and moreover several are connected in multiple on one circuit. The annunciator has an additional bell in the auxiliary circuit, which circuit is closed if any one of the drops operate. This bell will therefore continue to ring until some one restores the drops to their normal position. The annunciator has several attachments not found on the ordinary annunciator, such as a switch to throw the instrument off in the daytime, a switch by which the condition of the batteries may be tested, and another which is thrown when it is desired to test the condition of any circuit without the noise of the bell. Sometimes a clock is added which automatically throws off the instrument at any desired hour.

Q. What kind of battery cells are used with annunciator systems?

A. Cells of the so-called open-circuit type and usually some form of the zinc-carbon-sal-ammoniac cells.

Q. How many cells are necessary?

A. This depends entirely on the number of points on the instrument and upon the distance and size of wire. In houses, as a rule, four cells will be sufficient. If the distances are very long it will be necessary to increase the number of cells in series; and if the number of points on the instrument is large, as, for example, in hotels, then it will be desirable to connect several of the cells in multiple with each other.

Q. What principal systems of watchmen's clock are there?

A. The battery system and the magneto system.

Q. Explain how a battery system is arranged and operated.

A. The wiring of the system is similar to that of the simple annunciator system. The push-buttons are of such a shape that a circuit can be closed in them only by the insertion of a certain key that the watchman carries. The annunciator of the ordinary system when slightly modified becomes the watchman's clock, the signal bell and automatic set-back being omitted. The armature of each drop operates a needle which punctures a hole in the paper recording dial which is divided into spaces corresponding to the hours and fractions of an hour. This dial makes one complete turn in twelve hours, and therefore the position of the holes tells at what time the circuit was closed by the watchman. The dial also has a number of circles marked on it corresponding to the number of stations, and each needle pricks its holes in one of the circular spaces formed by these rings, so that a hole in a certain ring shows that the key has been put in the corresponding station push-button.

Q. How does a magneto system differ from a battery system?

A. The wiring and clock are practically the same, but instead of a special push-button to be operated by a key a small magneto is placed at each station. The watchman carries a handle by which he turns the shaft of the magneto armature. This sends a current through the corresponding coil at the clock and causes its needle to make a record.

Q. What are the advantages of a magneto system over the battery system?

A. There are no batteries to renew and to take care of and the watchman cannot make a proper record on the dial without actually going to the station; whereas with the battery system, if the watchman can get at the two wires leading to any station to connect them together, he can make the clock register just as well as by going to the station.

Q. What is a Lechanche cell?

A. A Lechanche cell has for one pole a zinc rod, for the other a carbon plate, and the two are immersed in a solution of sal-ammoniac. In addition to this there is a block of compressed manganese binoxide.

Q. What is the object of this manganese?

A. It prevents what is known as polarization of the cell.

Q. What are the effects of polarization?

A. The voltage is diminished and the resistance increased by the accumulation on the carbon plate of particles of hydrogen gases.

Q. What voltage does a single Lechanche cell produce?

A. About $1\frac{1}{2}$ volts.

Q. How could you obtain a voltage of 15 volts with Lechanche cells?

A. By connecting ten of them in series.

Q. What are dry cells, and what are their advantages and disadvantages?

A. They are cells in which the solution has been reduced to a pasty condition. Their only advantage is their greater portability; their disadvantages are a high resistance and greater polarization.

Q. Why and how is a zinc battery plate amalgamated?

A. Zincs are amalgamated so as to prevent the consumption of the metal when the circuit of the battery is open. The process of amalgamation consists of dipping the zinc into weak sulphuric acid until it is clean, and then rubbing mercury on its surface with a cloth until it looks bright all over.

Q. What is the best form of zinc pole, and why?

A. The best form is that which gives a cell of the least resistance, and this depends upon the form of the other pole. In order to diminish the resistance the plates should expose as much surface as is possible, and the distance between the plates should be as small as possible. Therefore, if the carbon pole is of cylindrical form the best shape for the zinc would be a hollow cylinder surrounding the carbon.

Q. Which is the better for a carbon plate, one which is very dense and close in structure or one which is porous?

A. The porous carbon is much better, as the oxygen taken up in the pores assists in removing the hydrogen particles that collect on the carbon plate and produce polarization.

Q. When cells of the zinc-carbon-sal-ammoniac type fail to operate properly, what would you do?

A. I would examine first the zinc plate and see if it were eaten up, and if so, I would replace it with a new one. If the zinc is all right I would examine the solution, and if this is of a yellowish color a new solution is needed. If the cell has been in use some time it will be desirable to boil the carbon plate for some time in water.

Q. Is the zinc-carbon-sal-ammoniac cell suitable for use in operating small motors or lamps?

A. No; the cell polarizes too readily; for such work the bichromate cell or the Edison-Lalande are adapted.

Q. Describe the bichromate cell.

A. The bichromate cell consists of a zinc and a carbon plate in a solution of chromic acid. As the zinc is attacked by chromic acid even when the circuit is open, the cell is arranged so that when not in use the zinc can be raised and held out of contact with the acid.

Q. What is the pressure furnished by a bichromate cell?

A. About 2 volts.

Q. Describe the Edison-Lalande cell.

A. The Edison-Lalande cell consists of a zinc and a copper oxide plate suspended in a solution of caustic potash.

Q. What is the pressure furnished by the Edison-Lalande cell ?

A. About $\frac{7}{10}$ volt.

Q. Will a larger size cell give a higher voltage than a small cell ?

A. No; the voltage is the same, but the resistance of the larger cell is less.

Q. In mixing up a sal-ammoniac solution, is it better to use warm or cold water ?

A. Warm water, because the sal-ammoniac when dissolving produces a considerable degree of cold, and this is liable to crack the glass jars.

Q. Describe the Daniell cell, gravity pattern.

A. The Daniell cell consists of a copper terminal made up of thin sheet copper, which is placed in the bottom of the glass jar; crystals of copper sulphate are strewn over the plate and water is added until the jar is nearly full. A zinc plate is suspended at the top of the jar and a little sulphuric acid added to start the cell.

Q. What is the voltage of the Daniell cell, and for what kind of work is it adapted ?

A. The voltage is about one volt. The cell is adapted to work in which the circuit is closed practically all the time, as in telegraph work and in certain signal systems.

Q. What kind of cells are used for operating burglar-alarm and watchmen's clock systems, and how many?

A. Some form of the zinc-carbon-sal-ammoniac cell. The number needed depends upon the distances and the clock used, but generally about six will be sufficient.

Q. When the wires of bell, burglar-alarm, or watchmen's clock system are installed in conduit, is there any limit to the number of wires that may be put in one tube?

A. As many wires may be put in one tube as can be readily drawn in and out.

Q. What kinds of wire are used for this class of work?

A. Generally a wire insulated with two layers of cotton dipped in paraffin, called annunciator wire, is used on account of its cheapness. Office wire, which is a heavier insulation of the same kind, is used generally for the battery or common wire. In better classes of work a rubber-covered wire is used for the common wire and a weather-proof or fire- and weather-proof insulation for the other wires.

Q. What are the two principal telephone systems?

A. The exchange system and the intercommunicating system.

Q. What is the difference between the arrangements of the two systems?

A. In the exchange system two wires run from a central point to each telephone subscriber. These wires are each connected to the drop or indicating device of the exchange switchboard. The exchange operator, by means of convenient plugs and cords, connects the circuit of any one subscriber to the circuit of the party with whom he desires to speak. In the intercommunicating system there are as many wires as there are instruments plus two or three common wires, and all of these wires run to each instrument terminating in a switch. By throwing this switch to the point corresponding to any desired party a subscriber puts himself in communication with that party.

Q. How does a subscriber call up Central on the exchange system?

A. There are two methods of calling: one where a battery and vibrating bell is used, the other where a magneto bell is placed at each instrument. The battery call is suitable for short distances only, while the magneto is equally good for short and long distances. At the exchange there is a sort of an annunciator device in each circuit, so that when the subscriber presses his button or turns the crank of his instrument, as the case may be, a corresponding shutter falls on the exchange switchboard.

Q. How are calls made by the exchange operator?

A. On the battery call system, the wiring and general arrangement being the same as for the return call annunciator system, the operator presses the button corresponding to the instrument of the subscriber desired. In the magneto-call system the operator has a magneto connected with a cord and plug. The plug is put into the drop corresponding to the subscriber desired, and the operator then turns her magneto handle which rings a magneto bell on the instrument.

Q. What method of calling is generally used on intercommunicating systems?

A. The battery call.

Q. For what kinds of work are the two systems adapted?

A. The intercommunicating system is adapted to installations of a few instruments where the distances are not great. Where the number of instruments is large the trouble from "cross-talk" becomes excessive, as does also the cost of wiring. In such cases it is advisable to use the exchange system.

Q. What is the general principle of the transmitter as now used?

A. The transmitter consists usually of a cup-shaped piece of carbon containing carbon granules or particles against which lies a thin carbon diaphragm; the whole is contained in a hard-rubber case to which is attached the mouthpiece. Current from a battery is led into the diaphragm and passes through the contacts between the diaphragm and the carbon particles, through the contacts between the particles themselves and to the contact between the particles or containing carbon cup, and afterward returns to the other pole of the battery. When the mouthpiece is spoken into, the diaphragm is set into vibration, producing a varying pressure of the carbon contacts, which varying pressure produces a varying resistance, and therefore a varying current which is transmitted along the line to the receiver of the other instrument.

Q. What is the general construction of the magneto receiver as now used?

A. The magneto receiver consists of the magnet, either bar shaped or preferably of the horseshoe pattern, on the pole or poles of which is mounted a coil of fine wire which is connected to the line. Close to this pole, but not quite touching, is a thin, circular, soft, iron diaphragm; the whole arrangement is enclosed in a hard-rubber case.

Q. What is the action of the receiver?

A. The varying currents produced by the transmitter flow along the line around the coils and produce a varying pull on the diaphragm, which sets the air into vibration affecting the ear.

Q. What kind of wire is used for telephone installations?

A. For inside work on exchange systems a weather-proof or rubber insulated wire, twisted every two inches or so, is employed; the size is about No. 18 or 20 B. & S. For single pairs of instruments or for intercommunicating work annunciator wire is used in the cheapest installations, and for a better class of work office wire or fire- and weather-proof is used.

Q. What kind of battery cells are used in telephone work?

A. Generally some form of the zinc-carbon-sal-ammoniac cell.

Q. Is the battery on a closed circuit when talking is not going on?

A. No; the battery is thrown off the circuit by an automatic hook which operates when the receiver is lifted off the hook.

Q. Mention some of the troubles which you have met in the various parts of the telephone system.

A. In transmitters: a packing of the carbon particles, breaking of the carbon diaphragm, bad connections from the battery to the transmitter, and running down of the battery from various causes. In the receiver: a broken wire in the coil, broken wire between the coil of the receiver and the receiver terminals, and touching of the diaphragm on the magneto pole. In the magneto: a grounding of the armature wire on the core or a broken wire on the armature, a bad connection between the armature and the terminals of the magneto. On the line: a ground, short circuit, or broken wire.

QUESTIONS ON ELECTRICAL UNITS, PROPERTIES, AND MEASUREMENT.

Q. What are the three most important electrical properties?

A. Current, electro-motive force, and resistance.

Q. What is another term for electro-motive force?

A. Electrical pressure.

Q. How may electrical pressure be produced?

A. The two most important methods are by means of chemical action and by the movement of a conductor near a magnet.

Q. What is the unit of electrical pressure?

A. The "volt."

Q. What is the instrument called that is used to measure electrical pressure?

A. The voltmeter.

Q. Whenever there is a difference of electrical pressure between any two points, what will happen if these two points are joined by a conductor?

A. An electrical current will flow from the high pressure point to the low so long as there continues to be a difference of pressure between the two points.

Q. Is there a mechanical pressure as well as an electrical pressure existing between the two points?

A. Yes; the substance which separates the two points is under an actual mechanical strain, the amount of strain increasing with the increase of electrical pressure.

Q. How could you ascertain whether there was a difference of pressure between two points?

A. By connecting a voltmeter between the two points. If the needle of the voltmeter were deflected, I should know that there was a difference of pressure between them.

Q. What is used as a convenient standard of pressure?

A. A certain kind of cell called the Clark cell.

Q. What are some of the effects of an electric current?

A. It heats conductors carrying it, it exerts a magnetic force on all magnetic substances near the conductors, and it is able to decompose the solutions of many chemical substances.

Q. What is the unit of current?

A. The ampère.

Q. What is the practical definition of an ampère?

A. An ampère is the current which will deposit from a solution of silver nitrate .017 grain of silver in one second.

Q. In the case of flowing water, what would be analogous to the ampère?

A. Since the ampère is the unit of rate of flow the corresponding unit for water would be a flow of one gallon per second.

Q. Is the heating effect of an electric current proportional to the strength of current?

A. It increases as the current increases, but very much faster; for example, doubling the current makes the heating effect four times as great; in fact, the heating effect is proportional to the square of the current.

Q. What practical use is made of the heating effect?

A. It is used in electric heaters and cooking devices, and in heating the filaments of incandescent lamps.

Q. Is there any danger in the heating effect?

A. There would be if the wires used for carrying currents were too small. In such a case the wires would become so heated as to be liable to set fire to woodwork in their vicinity.

Q. What relation exists between the magnetic effect of the current and the number of ampères?

A. The magnetic effect is strictly proportional to the number of ampères.

Q. Is the ability of the current to decompose substances also proportional to the number of ampères?

A. Yes; strictly so.

Q. What is the resistance of a conductor?

A. The resistance of a conductor is the opposition which that conductor offers to the passage of an electrical current.

Q. What is the unit of resistance?

A. The ohm.

Q. What is an ohm?

A. An ohm is the resistance of a column of mercury having a certain definite length (41.85 inches) and a certain weight (223 grains) at 32° Fahr.

Q. Are the standard ohms used in practice made of mercury?

A. No; they are made of wire coiled up in a convenient form.

Q. What effect has the length of the conductor upon its resistance?

A. The resistance is proportional to its length.

Q. How does increasing the cross-section of a conductor affect its resistance?

A. It lessens it proportionately.

Q. Suppose that a certain size of wire 1000 feet long has a resistance of two ohms, what will be the resistance of 500 feet of the same wire?

A. One ohm.

Q. And suppose that the diameter of the 500 feet of wire were made one-half its present value, what would the resistance be?

A. Since the diameter is halved, the new area will be one-quarter and the resistance will be four times as great, or four ohms.

Q. What is the difference between resistance and conductivity?

A. Resistance is the opposite of conductivity.

Q. When are two conductors said to be connected in series?

A. When they are placed like two horses driven tandem—that is, when one end of one conductor is joined to one end of the other.

Q. What is the total resistance of two conductors connected in series?

A. The total resistance is equal to the sum of the separate resistances.

Q. When are conductors said to be connected with multiple or parallel?

A. When they are placed like two horses driven as a pair, the conductors being connected to each other as follows:

If we may suppose the conductors to be lying in the north and south direction, the north ends will be connected and the south ends will be connected together.

Q. What is the rule for finding the joint resistance of two conductors connected in multiple?

A. Divide the product of the two resistances by the sum.

Q. When the resistances are equal, what will be the joint resistance?

A. One-half of the resistance of one of them.

Q. What is specific resistance?

A. It is the resistance of a cubic inch of a substance.

Q. What are non-conductors?

A. Substances that have a high specific substance; or, in other words, that offer a strong opposition to the passage of the current.

Q. What are conductors?

A. Substances having a comparatively low specific resistance.

Q. What is an insulator?

A. It is another name for a non-conductor.

Q. What class of substances are good conductors, and what class are insulators?

A. The metals are good conductors and the non-metals are insulators.

Q. What are some of the best conductors?

A. Copper and silver.

Q. What are some of the best insulators?

A. The best insulators are glass, porcelain, mica, rubber, and dry air.

Q. What is Ohm's law?

A. In an electric circuit the total current (in ampères) is equal to the total electric pressure (in volts) divided by the total resistance (in ohms).

Q. What formula is used to express this law?

A. $C = \frac{E}{R}$. Where C equals the current in ampères, E equals pressure in volts, and R equals resistance in ohms.

Q. Is this law applicable to circuits carrying an alternating current?

A. Not without modifications.

Q. A certain electric circuit has a total resistance of 4 ohms, and there is an electrical pressure acting amounting to 8 volts, what will be the current?

A. Two ampères.

Q. How great an electro-motive force will be needed to send a current of 10 ampères through a circuit having a resistance of 1 ohm?

A. Ten volts.

Q. Suppose that we find in a circuit a current of 20 ampères, and with the pressure in the circuit is 50 volts, what is the resistance of the circuit?

A. $\frac{50}{20}$, or $2\frac{1}{2}$ ohms.

Q. Suppose that we have connected up in series three batteries, each giving an electro-motive force of 1.5 volts, what will be the pressure between the unconnected ends of the series?

A. 3×1.5, or 4.5 volts.

Q. Now, suppose that connected in series with them is a wire having a resistance of 3 ohms, can you calculate what current will flow in the circuit?

A. Not unless I know the resistance of the batteries.

Q. If the resistance of the batteries is $\frac{1}{2}$ ohm each, what current will flow in this circuit? Explain how you will arrive at the result.

A. Since each battery has a resistance of $\frac{1}{2}$ ohm, the total resistance of the circuit will be $\frac{1}{2} + \frac{1}{2} + \frac{1}{2} + 3$, or $4\frac{1}{2}$ ohms. By Ohm's law the current $= \frac{4\frac{1}{2}}{4\frac{1}{2}}$, or 1 ampère.

Q. Suppose that one of the three batteries was reversed so that it opposes the other two, what would be the net electro-motive force in circuit?

A. 3 — $1\frac{1}{2}$, or $1\frac{1}{2}$ volts.

Q. When the electric pressure is furnished by the ordinary 110-volt generator, what will be the current flowing if one 16 c. p. lamp of 220 ohms resistance is turned on?

A. In this case the resistance of the generator is so small compared with the resistance of the circuit that it may be neglected in the calculation. The current will therefore be $\frac{110}{220}$, or $\frac{1}{2}$ ampère.

Q. What will be the current when two lamps are turned on?

A. By the rule for divided circuits the joint resistance is $\frac{220 \times 220}{220 + 220}$, or 110 ohms. The current will then be $\frac{110}{110}$, or 1 ampère. This is the total current flowing through the machine, one-half of it flowing through each lamp.

Q. What would be the current when ten lamps are turned on?

A. In this case, where the resistances of the separate branches are equal, the joint resistance is equal to the resistance of any one branch divided by the number of branches. The joint resistance is, therefore, $\frac{220}{10}$, or 22 ohms. The current will be $\frac{110}{22}$, or 5 ampères.

Q. What is a galvanometer, and how can one be made?

A. A galvanometer is an instrument for detecting or measuring a current. It may consist of a fixed coil of wire and a movable magnet needle which is deflected by any current passing through a coil, or the coil may be small and movable and the magnet large and fixed.

Q. What is the construction of the Weston instruments?

A. They consist of a fixed permanent magnet of horse-shoe form between the poles of which is pivoted a coil of fine wire. The indicating needle of the instrument is attached to the coil; the coil is held in the zero position by a bar of fine springs similar to the hair-spring of a watch. When the current passes through the coil, the coil is deflected against the action of these springs by an amount proportional to the current strength.

Q. How would you connect a voltmeter so as to measure the voltage of a battery?

A. I would connect one terminal of the voltmeter to one terminal of the battery, and the other terminal of the voltmeter to the other terminal of the battery.

Q. In the Weston instrument, does it make any difference which terminal is connected to the zinc pole of the battery?

A. Yes; the terminal marked minus (—) should be connected to the zinc pole, otherwise the needle will tend to deflect in the wrong direction.

Q. What is the most common range of a Weston portable voltmeter?

A. One reading from zero to 150 volts.

Q. Could you measure accurately with such an instrument the pressure of a single battery cell?

A. No; the reading would be so small as to be inaccurate; it would be like trying to weigh a small boy on a set of hay scales.

Q. Is there any way to measure accurately with such an instrument the pressure of a single cell?

A. No; the instruments are, however, often made with a double scale and a double set of terminals, the lower scale reading from zero to 5 or from zero to 15 volts.

Q. Suppose that with such an instrument you wish to measure a voltage which you knew to be in the vicinity of 220, how would you do it?

A. I would first connect across the circuit, whose pressure I desire to measure, two 110-volt lamps in series; then I would connect the voltmeter first so as to measure the pressure between the terminals of one of the lamps, and next between the terminals of the other lamp. The sum of the two pressures would be the pressure of the circuit desired.

Q. How would you connect the voltmeter so as to obtain the pressure between the terminals of the lamp?

A. I would connect a wire from one terminal of the lamp socket to one terminal of the voltmeter and another wire from the other terminal of the lamp socket to the other terminal of the voltmeter.

Q. How does the Weston ammeter differ from the voltmeter in construction?

A. A strip of heavy metal connects across the terminals of the coil so that it takes the bulk of the current to be measured, only a very small fraction passing around the coil.

Q. How would you connect an ammeter so as to measure the current passing through a certain number of incandescent lamps?

A. I would insert the ammeter in the branch circuit which supplies those lamps, opening the circuit at some convenient point and connecting one terminal of the opening to the proper terminal of the ammeter and the other side of the opening to the other terminal of the ammeter.

Q. Suppose that when you had connected up the ammeter you found that the needle was deflecting in the wrong direction?

A. I should know that the connections needed to be reversed; the plus terminal must be connected to the plus side of the circuit.

Q. Suppose that you had a coil of copper wire and wished to know its resistance, how could you find it out?

A. If I had access to wire tables I would measure first the gauge of the wire and would then either measure its length or weigh it, whichever were the easier. The ordinary wire tables give the resistance per 1000 feet of various gauges of wire and also the pounds per 1000 feet.

Q. How could you measure the resistance?

A. If I had an ammeter and voltmeter of proper range I would put the ammeter in series with the wire and pass a current through it. I would then connect the voltmeter to the terminals of the wire. The reading of the voltmeter would give the number of volts and the reading of the ammeter would give the number of ampères passing through the wire, and the quotient of the volts divided by the ampères is by Ohm's law the resistance in ohms.

Q. How great a current would you send through the wire?

A. That would depend upon the size of wire and the range of the ammeter. I would send a current large enough to give the maximum reading of the ammeter unless this heated the wire; in this case I would cut the current down until it produced no appreciable rise of temperature in the wire.

Q. Why would you not use a current great enough to heat the wire?

A. This would change the very thing which we want to measure—namely, the resistance.

Q. Is there any way of measuring resistance without the use of both voltmeter and ammeter?

A. Yes; the resistance may be measured by means of the voltmeter alone, provided we know its resistance.

Q. Explain how you would proceed to measure a resistance by the voltmeter alone.

A. See "Roper's Catechism," page 289.

Q. For what practical cases is this method largely used?

A. For measuring high resistances such as the insulation resistance of different parts of a dynamo from the frame and the insulation resistance of wiring circuits to earth.

Q. Show by a diagram how you would connect to measure the insulation of the armature coils of a dynamo from the frame.

A. See "Roper's Catechism," page 290.

Q. How would you measure the power used in any part of a direct current circuit, for instance, in a group of lamps?

A. I would connect an ammeter, so that the entire current which flows through the lamps also flows through the ammeter. I would connect a voltmeter across the branch circuit which supplies the lamps as near as possible to the lamps. I would read both instruments and multiply the readings together, thus obtaining the power in watts.

Q. How can you obtain the horse-power?

A. By dividing the number of watts by 746.

WHAT TO DO IN CASE OF ACCIDENTS.

FIRST AID TO THE INJURED.

Injuries caused by machinery are usually accompanied by bleeding. This bleeding may come from the arteries, which are the channels through which the blood passes on its way *from* the heart to the various parts of the body. In this case it is of a bright scarlet color, and escapes in spurts like water from a hose attached to a pump. Or the bleeding may come from the veins, which are the channels through which the blood flows on its way back to the heart. In this case the blood will be dark in color and will flow out in a steady stream without spurting. A third form of bleeding, known as *capillary bleeding*, consists in a leaking of blood from the smallest blood-vessels.

Capillary bleeding is easily stopped by folding up a piece of cloth or a handkerchief, placing it in the wound and tying it there.

Bleeding from the vein can be stopped by rolling up a handkerchief into a ball, placing it over the vein *below* the wound and then tying a second handkerchief tightly around so as to make the first handkerchief press hardly enough upon the vein to close the channel.

Arterial bleeding is by far the most dangerous, and it must be quickly and completely stopped. This is done by means of a so-called Spanish windlass (Fig. I), which consists of a piece of rope or cloth tied around the limb *above* the wound and then twisted up tightly by means of a stick. The arteries lie more deeply imbedded in the muscles than do the veins, and they cannot be completely compressed by the windlass unless a firm compress, made of a piece of wood, a small stone, or a rolled-up handkerchief, is laid over the artery. While one person is getting the windlass ready, the artery should be temporarily compressed by another person, who should grasp the limb with the fingers and put on as strong a pressure as possible with his thumbs.

In Figure II, *A* shows the location of the artery behind the knee-joint. At *B* it divides into two branches.

In Figure III, *A* indicates the location and the direction which the artery takes in the thigh.

In Figure IV, *A* is the artery in upper arm ; *C* and *B* the two arteries on the inner and outer side of the forearm.

The beating of the arteries can be recognized by feeling in their course, as indicated by the dia-

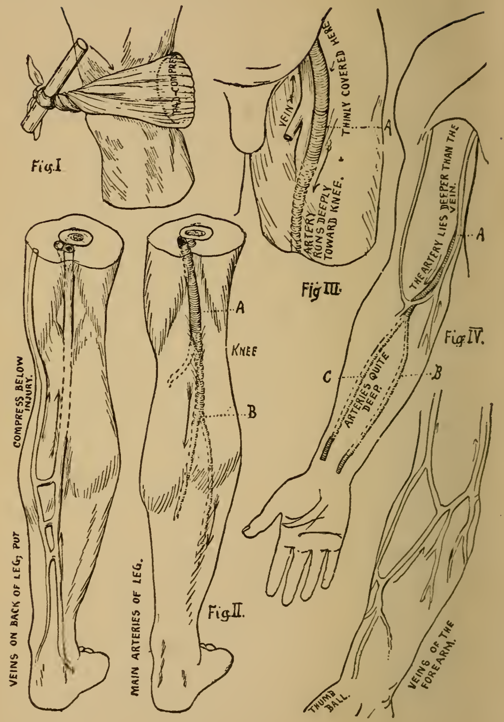


Fig. I
PAD-COMPRESS
VEIN
ARTERY RUNS DEEPLY TOWARD KNEE.
THINLY COVERED HERE
A
Fig III.
THE ARTERY LIES DEEPER THAN THE VEIN.
A
Fig. IV.
C
ARTERIES QUITE DEEP.
B
A
KNEE
B
COMPRESS BELOW INJURY.
VEINS ON BACK OF LEG; PUT
MAIN ARTERIES OF LEG.
Fig. II.
THUMB BALL.
VEINS OF THE FOREARM.

gram, and the compresses should be applied in these localities (above the cut or wound).

In addition to the above treatment, the application of ice or cold to the affected part is beneficial. Elevation of the injured limb also tends to check the bleeding.

Never make a man sit or stand up, if he has lost much blood, for he is very apt to faint, which may cause death.

It is always well to keep the head lower than any other part of the body, in order to prevent fainting and to decrease the work of the heart.

BURNS.

Burns may be divided, according to their extent, into three classes. *First*, those in which the skin is merely reddened. *Second*, those in which blisters are formed. *Third*, those in which the skin is either partially or wholly destroyed by charring.

The amount of danger depends entirely on the extent of surface affected, a complete destruction of one-third of the skin on the body usually proving fatal, while, if the skin is only reddened, two-thirds of the surface may be affected without death resulting.

TREATMENT.—As the results of scalds are the same as those of burns, they should receive the same treatment. The modern antiseptic methods require materials that are usually not at hand in an emergency case. The following steps may be taken previous to the arrival of the physician.

If the size of the burn is not very great, it is sufficient to wrap the affected part in cloths soaked with a strong solution of common *baking* soda in water. If this is not available, soak the cloths in a mixture of equal parts of sweet oil and lime-water.

If blisters have formed, prick them with a needle so as to let out the liquid, but be careful not to break or tear off the skin which covers the blister. Give a good drink of whiskey or two teaspoonfuls of aromatic spirits of ammonia.

If the burn be large, in addition to the above treatment the patient should be at once put to bed and covered with blankets. Hot-water bottles should be applied to his body, so as to keep up the temperature and to prevent shock, which would probably result fatally.